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UNITED STATES NAVAL OBSERVATORY.

W. W. PAYNE

It has been in our plans for some time to give our readers some views of the buildings and instruments of the United States Naval Observatory, but it has not been convenient to do so heretofore because we have not had at hand good photographs for the illustrations needed. By favor of Capt. C. M. Chester. Superintendent of the United States Naval Observatory and the kindness of W. W. Dinwiddie, assistant in spectroscopic work at the Observatory, we have secured some excellent photographs which will serve well for the illustrations to accompany a brief account of one of the leading astronomical observatories in America.

Our frontispiece is a front view of the main building as seen from the southwest. The entrance is at the center, and visitors by carriage or otherwise usually enter the building from the south side.

The circular part of the main building at the east end, is where the astronomical library is located. The dome on the west end covers the observing room for the twelve inch equatorial telescope. The interior of the main building contains the offices and the computing rooms for all the different branches of astronomical work closely connected with the Naval Observatory. The basement is used for the time service belonging to the Observatory. The transit instrument used in this service is in the separate building at the west end of the main structure. The walls of this building are of corrugated iron, with openings in the roof and sides, when the instrument is in use. They are closed in this photograph. In the first story of the main building are the computing rooms and the office of the *American Ephemeris* and *Nautical Almanac*. The director of the *Nautical Almanac* is Professor Walter S. Harshman.

The computing rooms for other work and the Superintendent's office are on the second floor. As already said above Captain C. M. Chester is superintendent of the Observatory. Visitors in at-

tendance at the last annual meeting of the American Association for the Advancement of Science and the meeting of the Astronomical and Astrophysical Society of America have spoken very favorably of the courtesies extended to them as visitors, by Superintendent Chester, during their visit at Washington.

This picture of the main building of the Observatory is an excellent one, as a whole, when one notices carefully the details of the building from end to end, the quite distinct focus in the foreground, the shadows, the leaves and the ground generally; and also, the far view of the dome above, and the fine cloud effect that is seen in all parts of the sky. Anyone who has tried to get all these results in harmonious tone in one picture knows better than we can describe it, what a difficult task it is to get a result like this, for it appears to come near nature's own handiwork; although the photographer has only the shades of white and black to aid him in this delicate work.

The accompanying cut is a picture of the old building used for Observatory purposes until the removal to the new at Georgetown Heights which has just been briefly described.

Our Government Observatory has a history well worth reading. Those who are interested in knowing the various stages of its growth and development from a very small beginning to the noble and commodious structures that now together make the United States Naval Observatory, will find an excellent resumè of its history in the report of the Board of Visitors to the Naval Observatory made in the year 1899 and printed at the Government printing office. This review goes back to 1815 and, in a connected story tells of the progress of the movement for a nautical Observatory, down to 1897 which was the time of the retirement of Professor Simon Newcomb from the position of Superintendent of the *American Ephemeris* and *Nautical Almanac* which occurred on March 12 of that year.

Some idea may be gained from a brief extract from that report of the work done in previous years, of the men who have performed it and of the instruments used.

"The new Observatory buildings on Georgetown Heights were first occupied in 1893. The instrumental equipment is for the most part new, few of the instruments of the old Observatory having been retained in their original form. An entirely new mounting was provided for the 26-inch equatorial telescope, and the 9.6-inch telescope was replaced by a new refractor of 12 inches aperture. A large spectrograph, of modern design, was furnished for the 26-inch telescope. Two new instruments, con-

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THE UNITED STATES NAVAL OBSERVATORY.

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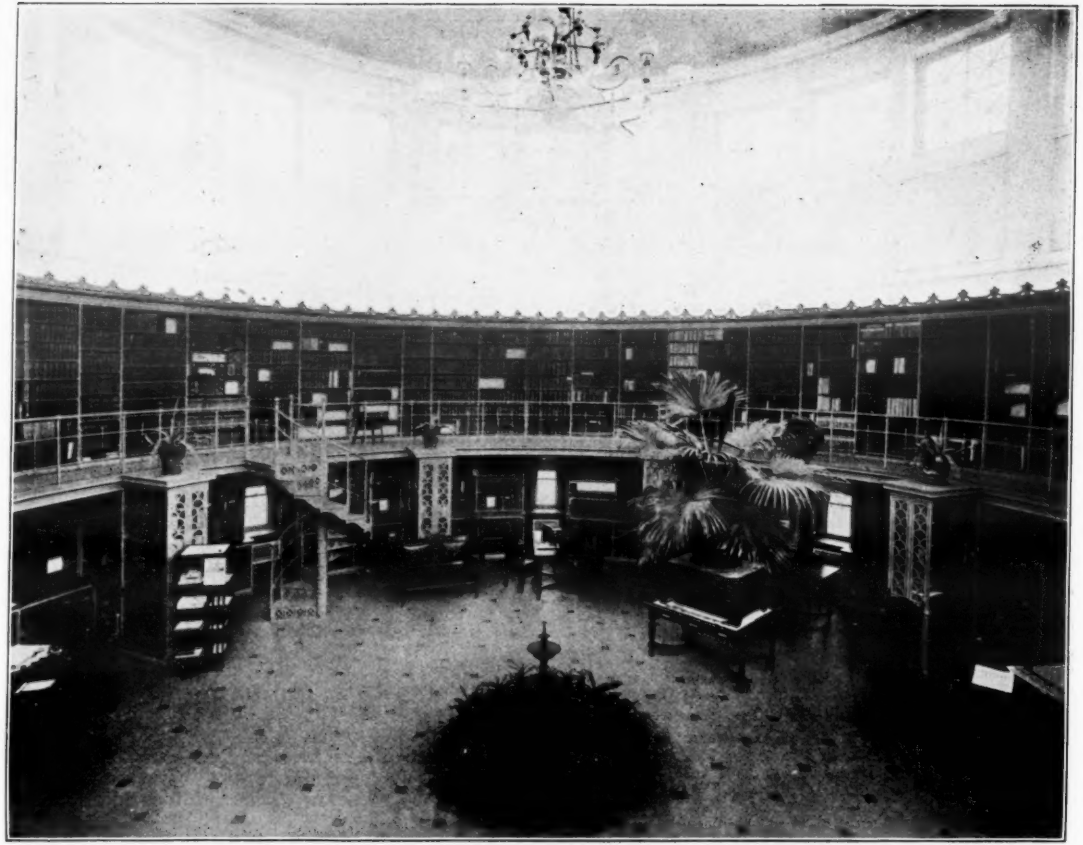
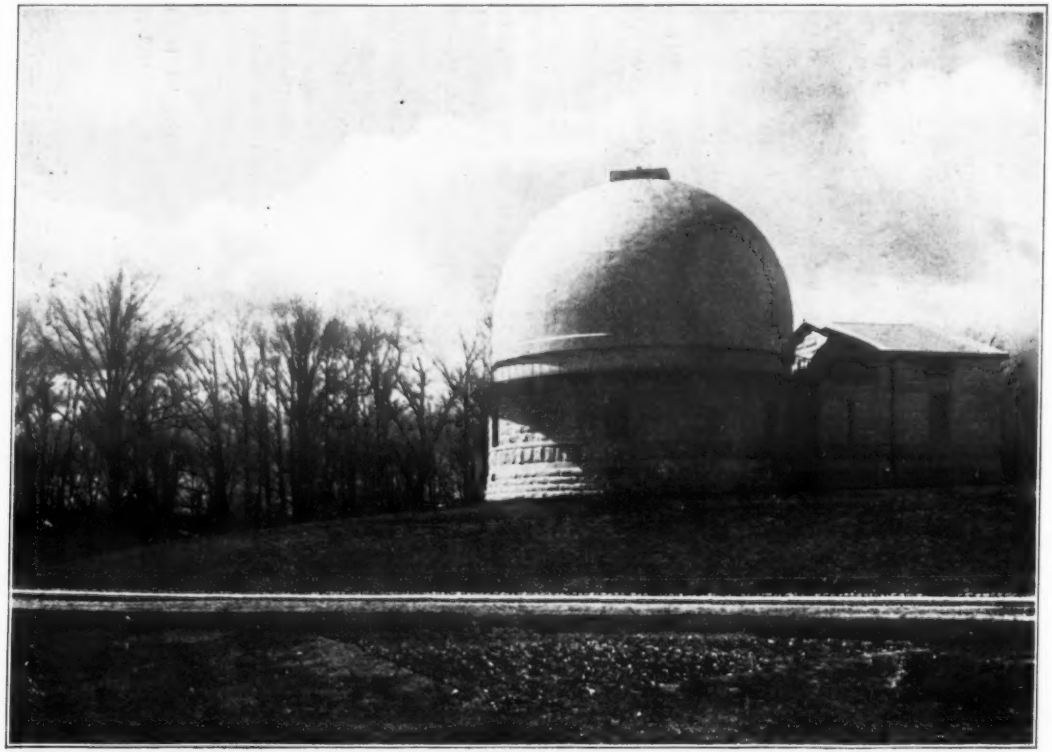


THE LIBRARY OF THE UNITED STATES NAVAL OBSERVATORY.

View from the Southeast.



HOUSE FOR THE 26-INCH EQUATORIAL.
View from the Southeast.

THE LIBRARY OF THE UNITED STATES NAVAL OBSERVATORY.

structed entirely of steel, were added to the equipment. One of these is a meridian circle of 6 inches aperture, and the other is a 5-inch alt-azimuth. The 8.5 inch Pistor & Martens meridian circle was furnished with a new objective of 9.1 inches aperture and the mounting was reconstructed. All the new instruments are of American make. The work of the Observatory since its removal to the new site has included observations of the Sun, Moon and planets and certain ephemeris stars (suspended from 1891 to 1894), observations of stars in the zone -13° 50′ to -18° 10′ of the *Astronomische Gesellschaft*, observations of selected stars with the prime vertical transit and the alt-azimuth, micrometric observations with the 26-inch and 12-inch telescopes. Some photographs of stellar spectra have been made with the spectrograph attached to the 26-inch telescope. The meteorological observations have been continued, but magnetic work (first seriously undertaken in 1881) has been given up, owing to disturbances caused by electric cars. Professor Yarnall's catalogue, containing the positions of all miscellaneous stars observed with the mural circle and transit instrument between 1845 and 1877 was published in 1878 (second edition). A third edition has since been brought out by Professor Frisby. Professor Eastman's catalogue of 5,151 stars, observed between 1866 and 1891, appeared in 1898. Of this catalogue the astronomical director remarks in a preface that it 'has absorbed the labors of about two-thirds of the Observatory staff for more than thirty years'."

The interior view of the Library is well shown in the accompanying picture. From it one can easily see its extent, its modern appointments, its central fountain and its mode of lighting for day or night. By the last report it was shown that the Library contains 18,378 volumes and 3,975 pamphlets.

The house for the 26-inch equatorial is well shown in the last cut presented in this brief outline. A description of the interior of this building with illustrations of the great equatorial telescope and the appliances that go well will be given in a following number of this publication. We will also present later cuts of some of the smaller instruments of modern pattern that have recently been added to the observing equipment.

We think it will interest our readers to have some knowledge of the personnel now employed and at work in the new Naval Observatory. Since the age of retirement is 58 years, it becomes necessary to make changes in the service often, comparatively, because those who are fitted for the leading places can not ordinarily be prepared for the responsibilities of them without long and faithful study and considerable experience in the various branches of practical astronomy.

ON THE PHYSICAL CONSTITUTION OF THE PLANET JUPITER.

G. W. HOUGH.

For Popular Astronomy.

The planet of Jupiter was one of the first objects to which the telescope of Galileo was directed, and the satellites of the planet were among the earliest discoveries made by that instrument. In 1630 the telescope had been constructed with sufficient power to show the great equatorial belt. Previous to the beginning of the 18th century the principal phenomena seen on the surface of Jupiter had been observed, and the time of rotation and position of the planet ascertained. Notwithstanding, however, the great mass of facts which have been collected from observations extending over a period of 200 years, yet up to the present time no theory of the physical condition of the surface has been advanced which has met with universal acceptance. In order that the subject may be more clearly understood it may be well to state briefly the salient features presented to the eye of the observer. The disk of Jupiter appears as an ellipse having axes in the ratio of 14 to 15, the longer axis lying in the direction of the planet's equator. The equatorial diameter is about 89,000 miles.

Now as the axis of the planet is nearly perpendicular to the line of sight, we will see objects in their true dimensions only near the middle of the disk and on the equator. In the revolution of the planet in its orbit, the equator, as seen from the Earth, may be displaced 3.3 degrees. Therefore all objects seen on the disk may apparently be shifted in latitude. At the equator the displacement may amount to $\pm$ 1″.1 of arc, or about one-sixteenth of the polar diameter, while in higher latitudes it will be very much less, and at the latitude of 70° the displacement will be only 0″.28 of arc.

During the past twenty-five years, some astronomers who have observed Jupiter for years, imagine that when the planet is turned with its axis three degrees toward the Earth, one would be able to see to the pole and beyond. I may say that this is a mistake for the reason that the displacement of three degrees would amount to only 0″.03 near the pole. It is very rare that any objects are seen beyond 40° of Jovian latitude. The latitude of 70° is only 1″ from the limb and 80°, only 0″.25 from the limb of the planet. Hence objects, if they existed at high latitudes, would be practically invisible. During 23 years of obser-

vation I have never observed a separate marking beyond 42° of Jovicentric latitude, or 5″.7 of arc from the limb, except on one night, when a small white spot was seen in latitude 62°, or within 2″ of the south limb of the planet. Usually a fine shading or discoloration of the disk is seen near the poles. The planet rotates on its axis in a little less than ten hours, and hence the shape and size of an object in passing across the disk will be materially modified by the effect of rotation. An object, when it is first brought into view on the disk by rotation is infinitely short in length and as it is brought farther on by rotation, the length is increased and reaches its maximum when on the central meridian of the disk. In passing off, it of course, goes through the same changes in apparent size. As the meridians on a globe are curved lines, objects in passing across the disk may apparently be displaced in longitude in regard to each other, due to the curvature of the meridian, *viz:* two spots lying in different latitudes might at one time be on a line parallel to the polar axis of the planet and, when brought on the middle of the disk, would lie in different longitudes. Some astronomers have been misled by phenomena of this kind, considering it to be a real motion of the object when in fact it is simply displacement due to rotation.

In order then to know what phenomena is real and what is apparent, it is necessary to take into account the position of the Earth with regard to Jupiter's equator, as well as the position of the object on the disk of the planet.

Jupiter is distant 5.2 times the distance of the Earth from the Sun, and at mean distance, 1″ of arc amounts to 2,300 miles. Now owing to the great distance of the planet from the Earth, the objects we see must have considerable size in order to be visible. I presume that the smallest object which has been observed for longitude or latitude is at least 2,000 miles in diameter. In the case of a line or streak one might be able to see with the aid of a modern telescope 0″.1 of arc in width, which on Jupiter would be 230 miles, but all the markings which have been observed are considerably greater in size than this minimum value. The ordinary spots we see on Jupiter, from which rotation time has been determined, have usually been upward of 3000 miles in diameter, where the spot is circular or elliptical.

I began systematic observations on Jupiter in the year 1879, and these have been continued every year with the exception of the opposition of 1888 and a part of 1889 when the telescope was dismounted. I may say that previous to this period the observation of phenomena have almost entirely been made by es-

timation. This was true with regard to the determination of longitude without exception, and very few positions in latitude have ever been determined with the micrometer. Amateur observers, who have no driving clock or micrometer, must necessarily rely on eye estimates for longitude and latitude, but when a telescope is equipped for micrometer work there is no better excuse for guessing than in the determination of the distance of a pair of double stars.

Sketches or drawings of the planet Jupiter are of very little value in the absence of other data. It is not unusual to find the latitude of conspicuous markings 8 or 10 degrees in error and longitude a corresponding amount. At the beginning of my observations on Jupiter I decided to fix the size and position of all objects seen on the disk by micrometrical measurement. By such a system of procedure positive facts will be established, which in time may enable us to correctly interpret the complicated phenomena observed.

During the past twenty-five years the so-called canals and double-canals on Mars have been the subject of much discussion. I believe if their position was fixed by micrometrical measurements, we would soon be able to decide what is real and what is imaginary.

In order to use the micrometer for measurements on a planet, it is necessary to know the size of the disk. Jupiter has been measured by many astronomers, both with the micrometer and with the heliometer, but the measurements made differ considerably, due to two causes. First, irradiation, which depends on the size of the telescope, or rather on the magnifying power employed. Second, the increased size of the image due to the condition of the atmosphere. In the case of the heliometer the true irradiation may be eliminated, but not the increased size of the disk due to definition. In any case the measured size of the disk depends directly on the magnifying power employed.

In 1880 I made a series of measures of the polar and equatorial diameter of the planet with powers of 390 and 638, and in 1897 a series of measurements with powers of 390 and 925. In all cases, whatever the condition of the seeing, the lower power gave the larger diameter. From the measures made on six nights in 1897, when the seeing was good enough to be able to use a power of 925, the difference for the two powers employed was, polar + 0″.27, equatorial + 0″.31. In 1880 for ordinary seeing the difference for the two powers employed amounted to 1″. In order therefore to have some standard of size it would be neces-

sary to decide upon the magnifying power employed with which the measures were made. Because of this apparent change in the size of the disk due to definition, to locate with precision any object on the surface of the disk, or a satellite off the disk, it is necessary to refer the object to both limbs of the planet at the time of observation. If the object is referred to only one limb, under unfavorable atmospheric conditions an error of 1″ of arc would be easily possible, but if it is referred to both limbs, then the effects of the irradiation, or enlargement of the disk, is almost wholly eliminated. In the reduction of my micrometrical work on Jupiter I have used the values 18″.33 and 19″.48 for the semi-axes of the planet at mean distance.

These values for the size of the disk were found from a great many differential measures made in 1880-81 with a power of 390 and are somewhat larger than those given by the heliometer, owing to irradiation, but they will probably better satisfy micrometer work.

The observations for longitude, latitude, and magnitude of objects on the planet Jupiter have all been made with the parallel wire micrometer, preferably near the central meridian, but no rigid rule is followed in this respect. The longitude and latitude are usually determined whenever the spot or marking is wholly on the disk and distinctly visible.

The longitudes are measured by ascertaining the distance of the apparent center of the object from the limbs of the planet, according to the method I pointed out some years ago. A determination of longitude or latitude generally consists of three bisections of the object and each limb of the planet. In the case of longitude, one-half of the difference of the distances at the the mean of the times is the distance of the apparent center of the object from the central meridian of the visible disk. This method of determining longitudes has been found to be greatly superior, in point of accuracy, to the method of transits, as well as a great saving of time.

The error in measurement of objects on a luminous disk is about twice as great as that from the measurement of double stars of equal distance. The ordinary error for location of objects in latitude of longitude on the disk of Jupiter may be placed at about 0″.25 arc.

Twenty-five years ago it was almost the general opinion among astronomers that the phenomena seen on the planet Jupiter were transitory in their nature, that there was no permanency in the spots and markings, but that the aspect of the planet changed

from day to day and even at less intervals of time. Perhaps we will get a better idea of what was known about the subject by quoting from Grant's "History of Physical Astronomy."

"Although generally there appears only three belts upon the disk of the planet, sometimes a greater variety is perceptible. Sometimes only one belt is visible. This is always the principal belt situated on the northern side of the planet's equator. On the other hand its whole surface has occasionally been seen covered with belts. On the 18th of January, 1790, Sir William Herschel, having observed the planet with his forty foot reflector, perceived two very dark belts dividing an equatorial zone of a yellowish color, and on each side of them were dark and bright bands alternating and continuous almost to the poles. A similar appearance was once noticed by Messier. These phenomena sometimes undergo very rapid transformation, affording thereby a strong proof that they owe their origin to the fluctuating movements of an elastic fluid enveloping the body of the planet. On the 13th of December, 1690, Cassini perceived five belts on the planet, two in the northern hemisphere and three in the southern hemisphere. An hour afterwards there appeared only two belts nearer the center and a feeble trace of the northern belt. The same astronomer frequently witnessed the formation of new belts on the planet in the course of one or two hours. The dark spots on the disk of the planet also afford unequivocal indications of the existence of an atmosphere, for it is impossible to reconcile their variable velocity with the supposition of their being permanent spots adhering to the surface of the planet. Cassini found from his observations that the spots near the equator of the planet revolved with greater velocity than those more distant from it. Sir William Herschel found that the velocity sometimes underwent a sensible change in the course of a few days. He supposed the spots to be large congeries of cloud suspended in the atmosphere of the planet, and he ascribes their movements to the prevalence of winds on its surface which blow periodically in the same direction."

Lardner in his Astronomy says, "In a month or two the whole aspect of the disk may be changed."

In my annual report to the Chicago Astronomical Society for the year 1881, I stated that the phenomena seen on the surface of Jupiter were of more permanent character than had hitherto been believed to be the case.

In 1878 a large and conspicuous object known as the Great Red Spot was seen on the disk of Jupiter. It appears that this

object was first noted on June 2d, 1878, by Lohse of Potsdam, but in looking up previous records, we find a spot seen in the same locality by the ancient astronomers. In the years 1664-5-6 a great red spot was observed by Hook and Cassini. It was situated one-third of the semi-diameter of the planet south of the equator in latitude — 6″. Its diameter was about 1/10 the diameter of Jupiter, or about 8,000 miles. This spot appeared and vanished eight times between the years 1665 and 1708. From 1708 to 1713 it was invisible; the longest time of its continuing to be visible was three years, and the longest period of its disappearing was five years. Since its appearance in 1878 it has been visible with large telescopes during the whole period, but at times so faint that except for the indentation in the equatorial belt, the spot perhaps would have been lost to astronomers, as it was formerly when they had smaller instruments.

The Great Red Spot is 11″.61 or 37°.2 in length, and 3″.87 in breadth, or about 27,000 miles long, 9,000 miles broad, elliptical in outline, and, if we suppose the depth of the spot equal to its width, its volume would be about three times that of the Earth. This object, which seems to have great permanency, is not stationary either in longitude or latitude.

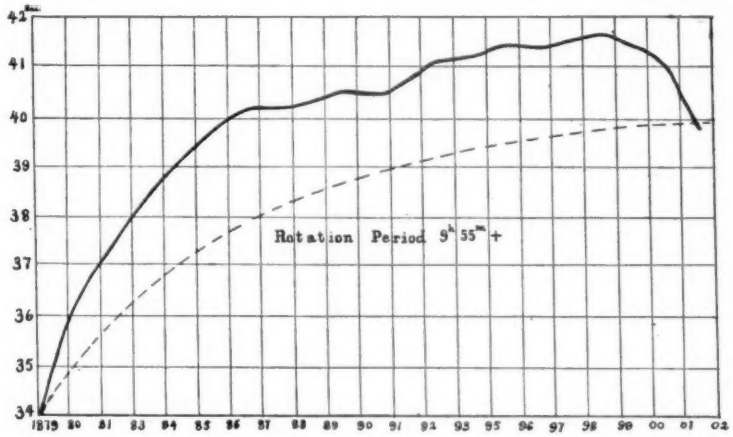
It was visible in 1869 and 1870 when it was observed by Gledhill on four nights from Nov. 14th to Jan. 25th, and on one night by Mayer. The data for ascertaining the rotation period has been derived from the drawings made, and necessarily are approximate.

The rotation period was $9^h\ 55^m\ 25^s.8$, or about eight seconds less than it was in 1879. From the observations made in 1878 I derived a rotation period $9^h\ 57^m\ 33^s.7$. Since the rotation period had been increasing for twenty years, the observations in 1869 are of value in tracing the motions of this object.

I may add that Mr. W. F. Denning, who has compiled the observations of what is presumed to be the red spot from 1831 to 1899, finds a rotation period of $9^h\ 55^m\ 34^s$ between 1869 and 1878, by assuming the number of rotations between consecutive observations. But where the interval is five years and upwards this is a very unsafe method of procedure, as will be perceived from the motions which have been studied during the last twenty-three years.

From the measures which I have made every year I have determined the rotation period for the red spot from 1879 up to the present time, and with the minimum value in 1879 of $9^h\ 55^m\ 34^s$. The diagram shows the rotation period at any point be-

tween 1879 and the present time. The vertical lines are intervals of 400 days, one day more than the synodic period of the planet. The time is counted from Sept. 25, 1879. The horizontal lines represent seconds of arc, so that the rotation period at any point will be shown on the curve, the seconds being at the left hand of the diagram, and the time at the bottom of the diagram. The rotations for this curve were computed for intervals of 400 days by using at each epoch about 12 normal places, and the probable error on the rotation period as determined in this way varies between $\pm$ 0^s.02 and $\pm$ 0^s.07. The curve is perfectly smooth for the first six years, showing that the motion of the spot was very regular. Since that period the curve is not absolutely smooth, which may be due to the faintness of the object, and the shifting

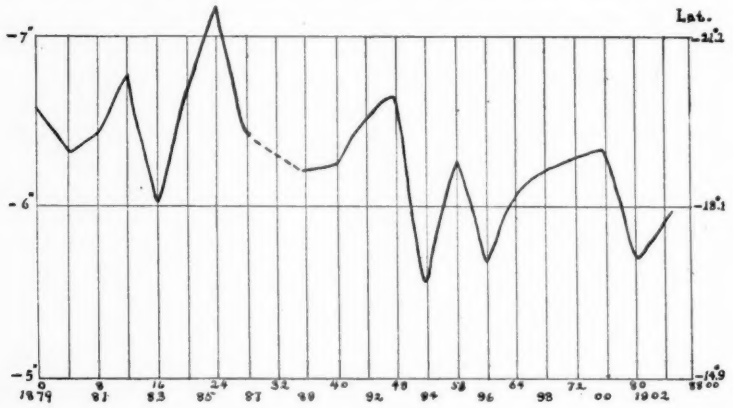


ROTATION PERIOD OF JUPITER—RED SPOT.

of the center from which the measurements were made, when the measures were referred to the bay in the equatorial belt. My measures, when the spot was very indistinct, have been referred to the center of the bay, and that may account for the small irregularities in the curve during the later years. From the diagram it is seen that the rotation period of the planet reached its maximum between 1898 and 1899, being 41^s.7. Previous to 1898 the spot had an apparent retrograde motion on the disk of the planet, and since that time the spot apparently has come to rest, and now has a direct drift around the planet. The rotation period for the last 400 day interval is 39^s.75, but the actual period at the present time is about three seconds less than it was

in 1889. Form the inspection of this curve, taken in connection with the rotation period which I found for 1870, it would seem to require a long cycle to make the rotation period the same as it was in 1879. The dotted curve indicates the "mean" rotation period at any instant, counting from September 25, 1879. The "mean" period for the interval 1879 to 1902 is $9^h\ 55^m\ 39^s.93$.

In 1880, when the red spot was most conspicuous, it has been seen when brought on the disk by rotation, at 87° of longitude, or $2^h\ 25^m$ in time from the central meridian, when its length was only one second of arc. When the spot is wholly on the disk its longitude is 71°.4 and the apparent length 3″.7. It is possible that the rotation period may be connected with its visibility, *viz:* when the spot comes back to the same rotation period it had in 1879 it may become more conspicuous and reddish in color. This object has drifted in longitude about 3¼ times around the planet since 1879, assuming the rotation period at that time to be the true rotation period of the planet. It seems to me, however, more probable that the time of rotation of the planet is



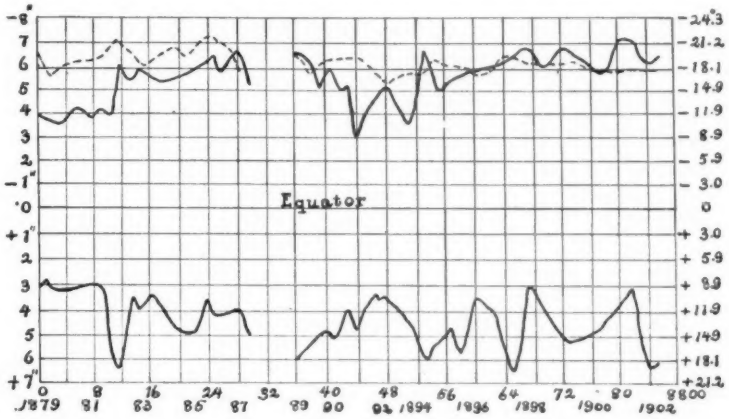
Drift of Red Spot in Latitude 1879 to 1902.

longer than any period hitherto determined, in which case all objects would drift in the same direction. The object also has a motion in latitude, and the total displacement in twenty-three years has been 1″.7, or about 4,000 miles drift in latitude. The rate of drift in longitude and the visibility may possibly be due to the greater or less submergence of the spot in the material which composes the surface of the planet.

The diagram indicates the latitude corrected for the elevation

of the Earth above Jupiter's equator. The curve was plotted from the mean of all observations made at each opposition. It seems that during twenty-three years the spot has approached nearly 1″ nearer the equator than it was in 1879. The short time scale, the vertical lines being intervals of 400 days, makes the displacement appear more abrupt than it really is. The Jovicentric latitude is given on the right hand of the diagram. At present this is about 18°. We might add that this displacement in latitude of the red spot is very much less than the displacement of the great equatorial belt.

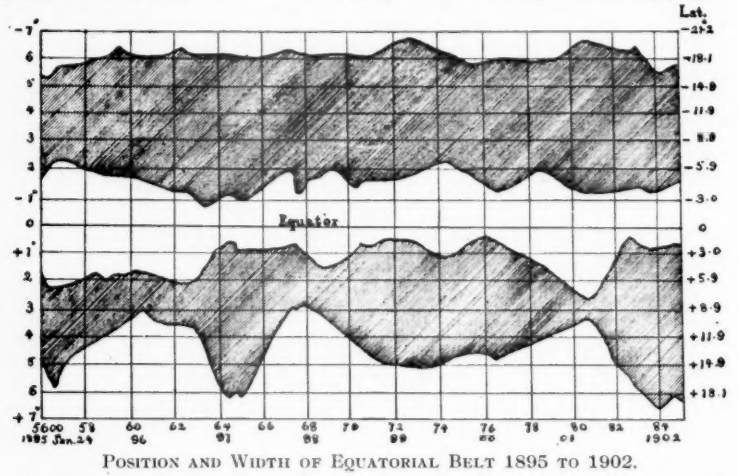
The most conspicuous marking on the surface of the planet is the great equatorial belt, which is always visible. This belt may appear as one belt, but usually is composed of two portions ly-



Latitude Equatorial Belt and Red Spot 1879 to 1902.

ing on either side of the equator of the planet. In 1880 it was practically one belt extending without break for a short time across the surface of the equator. From the study of the changes in this belt one may arrive at some idea regarding motions taking place on the surface of the planet. The systematic determination of motion in latitude has never been undertaken by any one previous to the observations which I began in 1879. Occasionally latitudes have been measured during one opposition. Arago in "Astronomie Populaire" raised the question whether the belts on Jupiter are fixed in size and position, and he gives some measures of the positions from 1811 to 1837, and takes the mean of these various measures for getting the mean position of the belts on the planet. These observations are approximate, and are

used without regard to the position of the Earth above and below Jupiter's equator. From 1879 to the present time the latitude and width of the great equatorial belt has been measured on nearly every observing night, so that we may ascertain the position of the edge of the belt at any instant. It is found that the north edge of the belt has had a drift in latitude of nearly 4″ of arc or 12° and the south edge about the same amount. The changes in the drift of the belt are usually slow and gradual, but it is possible sometimes that considerable change may be observed in the course of a few days. The diagram indicates the position of the edge of the belt from 1879 to 1902, and it is of very great interest in showing at a glance the changes that have taken place in latitude. From the study of this diagram it appears



Position and Width of Equatorial Belt 1895 to 1902.

that the disturbances take place on both edges of the belt at practically the same time. The matter composing the belts generally has a motion on both sides of the equator in opposite directions.

In 1879 the whole width of the belt was about 7″ of arc. In 1882 it widened out and has at times reached a width of about 13″ of arc. The edges of the belt remain practically parallel to the equator in all longitudes. I have noticed two marked exceptions. On October 3, 1882, there was a curved projection in longitude plus 30 minutes, following the great red spot. On October 14th the edge was smooth at the same longitude and the whole belt had drifted so far north as to coalesce with B_3. Also on February 24, 1897, in longitude plus five hours, the preceding

half of the north edge of the belt had drifted about 2″ farther north than the following portion. On February 27th, however, the edge of the belt was comparatively smooth in the same longitude.

Aside from the drift of the edges of the belt in latitude, the belt itself changes dimensions from time to time to a considerable extent, and these changes have been studied from micrometrical measurements since 1895. The diagram shows the width of the two portions of the equatorial belt at any instant from 1895 to 1902. The diagram indicates the width and not the shape of the belt at any time. Now it is seen, taking the portion of the belt north of the equator, at times it becomes very narrow, for instance in 1896 it was about 1″ of arc in width, 1897 it was about 5″ in width, and then it became narrower again in 1898, and continued wide from that time until 1901, when it was less than 1″ arc in width, and appeared as a faint line on the planet. The south portion of the belt has not passed through so great change during the five years, and has been more steady in latitude and width.

On either side of the equator are fainter belts which usually extend to 40° of latitude as separate belts. These faint belts are subject to change, both in size and position, from year to year.

On the belts and on the surface of the planet there are frequently seen small spots sometimes white and sometimes black, *viz:* 2000 miles or more in diameter, and from the observations of these spots we have determined the rotation period of the planet for different parts of the surface. The spots, which appear near the north margin of the equatorial belt nearly every opposition, and are sometimes permanent for two or three years, have a slight motion in latitude, only a fraction of 1″ of arc, whereas the belt may move 3″ or more in latitude in one year. It seems to me that this fact has an important bearing as to location of the objects, *viz:* the belt and the spots. I infer from the slight displacement of the spots that they lie at a lower level in the Jovian surface than the equatorial belt, and for the same reason the great red spot also lies at a lower level.

The transits of the satellites of Jupiter offer phenomena which have a direct bearing on the constitution of the planet. The satellites at times cross all parts of the disk in transit. For a normal transit the satellite disappears at some distance from the limbs after ingress and reappears at a similar distance before egress. From this fact it is concluded that the center of the disk of Jupiter has the same reflecting power as the satellites. With

the 18½″ refractor I have ascertained that a satellite can be followed for a distance of 10″ of arc from the limb or nearly one quarter the diameter of the disk before it disappeared in transit. However, when the transit occurs within 10″ of the north and south limbs, the satellite can be seen during the entire transit across the disk. Now since the satellite is not supposed to be hot enough to give light, we conclude there is not sufficient heat in the planet to produce light. The observation of the eclipses of the satellites also shows that it has no inherent light of its own.

Aside from the period of $9^h\ 55^m$ + some spots and markings give a shorter period of $9^h\ 50^m$ ± indicating that these objects have a motion of about 250 miles an hour in the direction of the planet's rotation, assuming that the true rotation period is $9^h\ 55^m$+. For mechanical reasons the spots which give this shorter period must necessarily be located above the spots which give the longer period of $9^h\ 55^m$ +. From 1879 to 1885 two white spots in latitude 6° south were observed every year, giving a rotation period of $9^h\ 50^m$ +. The white spots, during the last twenty-three years, which give this short period, have been observed between the latitudes +11 and −8, and also on one year, in 1891, black spots which gave a short period were observed in latitude 20° north. The spots and markings which give the long period of $9^h\ 55^m$ + have been observed in latitudes between 37° north and 38° south and within 12° of the equator.

The equatorial belt sometimes approaches the equator very closely, and its rotation for some years has been the same as that of the great red spot, for the spot and the belt have, as we know, maintained the same position toward each other. Hence we find the longer rotation period of $9^h\ 55^m$ + in precisely the same latitude as the shorter period. On examining the table of rotations, there does not seem to be any connection between latitude and rotation period as has often been alleged. The longest period which I observed, covering an interval of 156 days is $9^h\ 56^m\ 0^s.4$ which was in latitude 26° north.

Mr. A. S. Williams has written some articles on the rotation of the surface of Jupiter in which he finds zones of constant currents. These speculations are not sound, for the reason that in the same latitude we find different rotation periods for the same instant of time, and as I have said before there is no law connecting rotation period with the latitude except that we find this period of $9^h\ 50^m$ more commonly between the limits of − 8 and + 11°, whereas the longer period is distributed indiscriminately over the surface of the whole planet as far as 38° latitude.

The question has sometimes been raised as to whether the phenomena on Jupiter were periodic. The inclination of Jupiter's equator to its orbit being only 3°, any periodicity due to the revolution of Jupiter around the Sun should recur at intervals of about twelve years, but from the motions which I have shown for the displacement of the belts in latitude there does not seem to be any regularity in the period. I presume any periodicity is of the same nature as we have in the meteorology of the Earth. We have of course a sequence in the seasons and a sequence in weather conditions, but our sequence in weather conditions do not follow any regularity, and if changes on Jupiter are due to meteorological causes, we should not expect to find any definite period.

The application of photography to astronomical observations has been of great value in various directions, but up to the present time it has been of no benefit in the study of planetary details. Photographs of the planet Jupiter have been made since 1880 at different times, but they only show the simple outline and some of the conspicuous markings. The scale of the photograph is so small that it cannot be used with any degree of success for the determining position on the disk. There is no question, however, that if we are ever able, by increasing the sensitiveness of our plate, to make an enlarged photograph of Jupiter or Mars such as is seen through the telescope with the eye, it would be a great advance, and it would enable us to decide very many questions, which are now impossible owing to the limited time that we are able to study the object under consideration, due to the rapid motion of the planet on its axis. The phenomena seen on the planet depend in a great measure on the size of the telescope and the magnifying power employed. In my work on Jupiter I have habitually used a power of 390, which is adapted to most conditions for seeing and will show minute detail. With the same telescope, using a power of 190, the appearance of the disk is quite different and minute detail cannot be seen with distinctness. The observers who have small telescopes of five or six inches in aperture and use a comparatively low power do not see the phenomena as it would be shown by larger telescopes and high power. Hence on any question of disagreement, observations with the small telescope should have very little weight. The principle is precisely the same as in the observation of double stars. While a pair of close or unequal double stars may be easy objects for the 18½″ object glass, they are entirely beyond the range of a 6″ object glass.

A misinterpretation of phenomena has given rise to very erroneous notions regarding the changes which take place on the surface of the planet. When we look at the planet Jupiter, we see only about one-fifth of the surface in longitude distinctly at any one time, and hence in the course of two hours we would have entirely a new set of features under view of the eye of the observer. The faint belts north and south of equator sometimes extend over a portion of the circumference of the planet, and in such case one might see a greater or less number of belts after the interval of two hours or more, as has been stated by Cassini and others.

My observations during the past twenty-three years have established the following facts:

(1). The equatorial belt changes both in size and position to a considerable extent, but these changes are usually slow and gradual. Occasionally, however, a marked change may be observed in the features of the belt in the course of a number of days.

(2). The fainter belts also are displaced in latitude and in the amount of material of which they are composed. The visibility of the fainter markings and spots depends in a considerable measure on the distance of the planet from the Earth. When the planet is at more than mean distance, the so-called polar belts are very faint and sometimes invisible, even with a large telescope, and are not brought into view until the planet approaches toward opposition. This fact I noticed particularly in the early years of my observations on Jupiter, when the observations were made as near the Sun as possible.

(3). The egg-shaped white spots, which appear in this form from perspective, as they are probably nearly circular, are found both north and south of the equator and are very permanent in latitude. They are usually from one to two seconds of arc in diameter. These spots are not fixed with regard to each other, even when they are located in the same latitude.

(4). Aside from the white spots, there are dark spots of similar size, sometimes on the faint belts and sometimes entirely disconnected from the belt. The dark matter is not as stable as the egg-shaped white spots, and probably lies at the same level as the equatorial belt.

(5). Near the equator are found white spots, usually of a larger size and more irregular in shape, which give rise to the period of $9^h\ 50^m$.

The mean density of the planet Jupiter is 1.37 times that of

water. The spheroidal figure of the planet indicates that the density increases as we proceed from the surface to the center. In the case of the Earth the density at the surface is about one-third the mean density, and assuming the same rule for Jupiter its surface density would be 0.4 to 0.5 that of water. The liquefaction of air and gases during recent years enables us to imagine a medium which would have the density corresponding to that of the surface of the planet. The older astronomers, of course, had no knowledge of any substance between atmosphere and liquid, and hence in forming their theories of the motions on the surface of the planet, the theory was necessarily atmospheric, but there is now no excuse for maintaining an atmospheric theory which will not account for the phenomena observed.

A probable theory of the constitution of the planet should in some degree satisfy all phenomena observed. No one can draw legitimate conclusions from casual observations. On the surface of Jupiter we find the following objects: (1). The great red spot, which is the most stable of all objects seen on the disk of the planet. During the period that its size has been measured with the micrometer one cannot say with certainty that there has been any change in its size or shape from 1879 to 1902. It is now conceded by astronomers that the object is identical with the spot observed by early astronomers. Such being the case, it would seem to be absurd to say that anything in the nature of a cloud should persist in the same form for more than 200 years. Its spheroidal shape in connection with its stability would seem to show that it has volume and mass. Its motion in latitude, as we have already seen, is much less than for the equatorial belt. The matter of which it is composed is in a different condition to that of the belt. In 1880 I had the good fortune to notice the transit of a satellite over the red spot. The satellite, which was invisible during transit, when projected on the spot, appeared as bright as when off the disk. On the contrary when satellites transit the belt they are invisible.

(2). Egg-shaped white spots from 2000 to 5000 miles in diameter. These spots I have found in north latitude 13° to 37° and in south latitude from 18° to 27°. These objects do not look like clouds and so far as we know they do not change their shape during the six months while under observation. They are also very stable in latitude and give a rotation period of $9^h\ 55^m +$, (3). Small black spots seen on the belt or entirely separate. These objects give a rotation period of $9^h\ 55^m +$, but on one occasion in latitude 20° north I found a shorter period. (4). The

dark matter forming the system of belts including the equatorial belt and the so-called polar belts, which also give a rotation period of $9^h\ 55^m +$. (5). The white spots which give a rotation period of $5^h\ 50^m$.

It seems to be the opinion of most writers on Jovian phenomena that the planet is yet at a high temperature, but not self-luminous. The high temperature is favorable for the explanation of some of the phenomena observed. I have long held the opinion that a simple atmospheric theory was not sufficient. The greater luminosity of the center of the disk indicates absorption of light, probably due to an extensive atmosphere. The white spots which give a rotation period of $9^h\ 50^m$ are of different form and size from the egg-shaped spots which give the period of $9^h\ 55^m +$. The short period spots are greater in size and irregular in shape, sometimes appearing simply as a rift in the equatorial belt. Having these facts before us, we can formulate a theory which will fairly well satisfy all classes of phenomena. First, I assumed that the visible boundary of Jupiter has a density of about one-half that of water. This medium is in the nature of a liquid, and in it are located the great red spot and the egg-shaped white spots. In such a medium all motions in longitude and latitude would be slow and gradual, and the shape and size of the object would have great permanency. The equatorial belt and the so-called polar belts may be located on the surface or at a higher level than the red spot. In the middle latitudes within twenty degrees of the equator the higher atmosphere carries a layer of dark material in the direction of the rotation of the planet at a velocity of about 250 miles per hour, making a complete circuit around the planet in 44 days. In this envelope are formed the openings which we call white spots and, by unequal distribution, black spots. The great bay in the south edge of the equatorial belt may be accounted for by assuming that the great red spot is at a lower temperature than the medium in which it floats, and by its lower temperature condensing a portion of the vapor composing the belt. In 1882 when the edge of the belt drifted south it did not come in contact with the spot at any point, although it advanced at times beyond the center. In 1883 I stated that the spot seemed to have a repelling influence on the belt. During the past twenty years when the belt and the spot were in proximity a depression was formed in the belt directly opposite, which was of the same form as the contour of the spot. The belts may be assumed to be some sort of vapor of considerable density. The cloud-like matter, which

in the equatorial regions is moving over the surface at the rate of 250 miles per hour would account for the minor changes on the surface of the equatorial belt. I think the theory I have given offers a more plausible explanation of the various phenomena observed than the off-hand statement that we see simply clouds floating in the atmosphere of the planet.

LIQUEFACTION OF GASES AND LOW TEMPERATURES.

[CONTINUED FROM PAGE 16.]

THE UPPER AIR AND AURORAS.

The present liquid ocean, neglecting everything for the moment but the water, was at a previous period of the Earth's history part of the atmosphere, and its condensation has been brought about by the gradual cooling of the Earth's surface. This resulting ocean is subjected to the pressure of the remaining uncondensed gases, and as these are slightly soluble they dissolve to some extent in the fluid. The gases in solution can be taken out by distillation or by exhausting the water, and if we compare their volume with the volume of water as steam, we should find about 1 volume of air in 60,000 volumes of steam. This would then be about the rough proportion of the relatively permanent gas to condensable gas which existed in the case of the vaporized ocean. Now let us assume the surface of the Earth gradually cooled to some 200 degrees below the freezing point; then, after all the present ocean was frozen, and the climate became three times more intense than any Arctic frost, a new ocean of liquid air would appear, covering the entire surface of the frozen globe about thirty-five feet deep. We may now apply the same reasoning to the liquid air ocean that we formerly did to the water one, and this would lead us to anticipate that it might contain in solution some gases that may be far less condensable than the chief constituents of the fluid. In order to separate them we must imitate the method of taking the gases out of water. Assume a sample of liquid air cooled to the low temperature that can be reached by its own evaporation, connected by a pipe to a condenser cooled in liquid hydrogen; then any volatile gases present in solution will distil over with the first portions of the air, and can be pumped off, being uncondensable at the temperature of the condenser. In this way, a gas mixture, containing, of the known gases, free hydrogen, helium and neon, has been separated

from liquid air. It is interesting to note in passing that the relative volatilities of water and oxygen are in the same ratio as those of liquid air and hydrogen, so that the analogy between the ocean of water and that of liquid air has another suggestive parallel. The total uncondensable gas separated in this way amounts to about one fifty-thousandth of the volume of the air, which is about the same proportion as the air dissolved in water. That free hydrogen exists in air in small amount is conclusively proved, but the actual proportion found by the process is very much smaller than Gautier has estimated by the combustion method. The recent experiments of Lord Rayleigh show that Gautier, who estimated the hydrogen present as one five-thousandth, has in some way produced more hydrogen than he can manage to extract from pure air by a repetition of the same process. The spectroscopic examination of these gases throws new light upon the question of the aurora and the nature of the upper air. On passing electric discharges through the tubes containing the most volatile of the atmospheric gases, they glow with a bright orange light, which is especially marked at the negative pole. The spectroscope shows that this light consists, in the visible part of the spectrum, chiefly of a succession of strong rays in red, orange and yellow, attributed to hydrogen, helium and neon. Besides these, a vast number of rays, generally less brilliant, are distributed through the whole length of the visible spectrum. The greater part of these rays are of, as yet, unknown origin. The violet and ultra-violet part of the spectrum rivals in strength that of the red and yellow rays. As these gases probably include some of the gases that pervade interplanetary space, search was made for the prominent nebular, coronal and auroral lines. No definite lines agreeing with the nebular spectrum could be found, but many lines occurred closely coincident with the coronal and auroral spectrum. But before discussing the spectroscopic problem it will be necessary to consider the nature and condition of the upper air.

According to the old law of Dalton, supported by the modern dynamical theory of gases, each constituent of the atmosphere while acted upon by the force of gravity forms a separate atmosphere, completely independent, except as to temperature, of the others, and the relations between the common temperature and the pressure and altitude for each specific atmosphere can be definitely expressed. If we assume the altitude and temperature known, then the pressure can be ascertained for the same height in the case of each of the gaseous constituents, and in this way

the percentage composition of the atmosphere at that place may be deduced. Suppose we start with a surface atmosphere having the composition of our air, only containing two ten-thousandths of hydrogen, then at thirty-seven miles, if a sample could be procured for analysis, we believe that it would be found to contain 12 per cent of hydrogen, and only 10 per cent of oxygen. The carbonic acid practically disappears; and by the time we reach forty-seven miles, where the temperature is *minus* 132 degrees, assuming a gradient of 3.2 degrees per mile, the nitrogen and oxygen have so thinned out that the only constituent of the upper air which is left is hydrogen. If the gradient of temperature were doubled, the elimination of the nitrogen and oxygen would take place by the time thirty-seven miles was reached, with a temperature of *minus* 220 degrees. The permanence of the composition of the air at the highest altitudes, as deduced from the basis of the dynamical theory of gases, has been discussed by Stoney, Bryan and others. It would appear that there is a concensus of opinion that the rate at which gases like hydrogen and helium could escape from the Earth's atmosphere would be excessively slow. Considering that to compensate any such loss the same gases are being supplied by actions taking place in the crust of the Earth, we may safely regard them as necessarily permanent constituents of the upper air. The temperature at the elevations we have been discussing would not be sufficient to cause any liquefaction of the nitrogen and oxygen, the pressure being so low. If we assume the mean temperature as about the boiling point of oxygen at atmospheric pressure, then a considerable amount of the carbonic acid must solidify as a mist, if the air from a lower level be cooled to this temperature; and the same result might take place with other gases of relatively small volatility which occur in air. This would explain the clouds that have been seen at an elevation of fifty miles, without assuming the possibility of water vapor being carried up so high. The temperature of the upper air must be above that on the vapor pressure curve corresponding to the barometric pressure at the locality, otherwise liquid condensation must take place. In other words, the temperature must be above the dew point of air at that place. At higher elevations, on any reasonable assumption of temperature distribution, we inevitably reach a temperature where the air would condense, just as Fourier and Poisson supposed it would, unless the temperature is arrested in some way from approaching the zero. Both ultra-violet absorption and the prevalence of electric storms may have something

to do with the maintenance of a higher mean temperature. The whole mass of the air above forty miles is not more than one seven-hundredth part of the total mass of the atmosphere, so that any rain or snow of liquid or solid air, if it did occur, would necessarily be of a very tenuous description. In any case, the dense gases tend to accumulate in the lower strata, and the lighter ones to predominate at the higher altitudes, always assuming that a steady state of equilibrium has been reached. It must be observed, however, that a sample of air taken at an elevation of nine miles has shown no difference in composition from that at the ground, whereas, according to our hypothesis, the oxygen ought to have been diminished to 17 per cent, and the carbonic acid should also have become much less. This can only be explained by assuming that a large intermixture of different layers of the atmosphere is still taking place at this elevation. This is confirmed by a study of the motions of clouds about six miles high which reveals an average velocity of the air currents of some seventy miles an hour; such violent winds must be the means of causing the intermingling of different atmospheric strata. Some clouds, however, during hot and thundery weather, have been seen to reach an elevation of seventeen miles, so that we have direct proof that on occasion the lower layers of atmosphere are carried to a great elevation. The existence of an atmosphere at more than a hundred miles above the surface of the Earth is revealed to us by the appearance of meteors and fireballs, and when we can take photographs of the spectrum of such apparitions we shall learn a great deal about the composition of the upper air. In the meantime Pickering's solitary spectrum of a meteor reveals an atmosphere of hydrogen and helium, and so far this is corroborative of the doctrine we have been discussing. It has long been recognized that the aurora is the result of electric discharges within the limits of the Earth's atmosphere, but it was difficult to understand why its spectrum should be so entirely different from anything which could be produced artificially by electric discharges through rarified air at the surface of the Earth. Writing in 1879, Rand Capron, after collecting all the recorded observations was able to enumerate no more than nine auroral rays, of which but one could with any probability be identified with rays emitted by atmospheric air under an electric discharge. Vogel attributed this want of agreement between nature and experiment, in a vague way, to difference of temperature and pressure; and Zollner thought the auroral spectrum to be one of a different order, in the sense in which

the line and band spectra of nitrogen are said to be of different orders. Such statements were merely confessions of ignorance. But since that time observations of the spectra of auroras have been greatly multiplied, chiefly through the Swedish and Danish Polar Expeditions, and the length of spectrum recorded on the ultra-violet side has been greatly extended by the use of photography, so that, in a recent discussion of the results, M. Henri Stassano is able to enumerate upwards of one hundred auroral rays, of which the wave-length is more or less approximately known, some of them far in the ultra-violet. Of this large number of rays he is able to identify, within the probable limits of errors of observation, about two-thirds as rays, which Professor Liveing and myself have observed to be emitted by the most volatile gases of atmospheric air unliquefiable at the temperature of liquid hydrogen. Most of the remainder he ascribes to argon, and some he might, with more probability, have identified with krypton or xenon rays, if he had been aware of the publication of wave-lengths of the spectra of those gases, and the identification of one of the highest rays of krypton with that most characteristic of auroras. The rosy tint often seen in auroras, particularly in the streamers, appears to be due mainly to neon, of which the spectrum is remarkably rich in red and orange rays. One or two neon rays are amongst those most frequently observed, while the red ray of hydrogen and one red ray of krypton have been noticed only once. The predominance of neon is not surprising, seeing that from its relatively greater proportion in air and its low density it must tend to concentrate at higher elevations. So large a number of probable identifications warrants the belief that we may yet be able to reproduce in our laboratories the auroral spectrum in its entirety. It is true that we have still to account for the appearance of some, and the absence of other, rays of the newly discovered gases, which in the way in which we stimulate them appear to be equally brilliant, and for the absence, with one doubtful exception, of all the rays of nitrogen. If we cannot give the reason of this, it is because we do not know the mechanism of luminescence—nor even whether the particles which carry the electricity are themselves luminous, or whether they only produce stresses causing other particles which encounter them to vibrate; yet we are certain that an electric discharge in a highly rarified mixture of gases lights one element and not another, in a way which, to our ignorance, seems capricious. The Swedish North Polar Expedition concluded from a great number of trigonometrical measurements that the average

above the ground of the base of the aurora was fifty kilometres (thirty-four miles) at Cape Thorsden, Spitzbergen; at this height the pressure of the nitrogen of the atmosphere would be only about one-tenth of a millimeter, and Moissan and Deslandres have found that in atmospheric air at pressures less than one millimeter the rays of nitrogen and oxygen fade and are replaced by those of argon and by five new rays which Stassano identifies with rays of the more volatile gases measured by us. Also Collie and Ramsay's observations on the distance to which electrical discharges of equal potential traverse different gases explosively throw much light on the question; for they find that, while for helium and neon this distance is from 250 to 300mm., for argon it is 45½mm., for hydrogen it is 39mm., and for air and oxygen it is still less. This indicates that a good deal depends on the very constitution of the gases themselves, and certainly helps us to understand why neon and argon, which exist in the atmosphere in larger proportions than helium, krypton or xenon, should make their appearance in the spectrum of auroras almost to the exclusion of nitrogen and oxygen. How much depends, not only on the constitution and it may be temperature of the gases, but also on the character of the electric discharge, is evident from the difference between the spectra at the cathode and anode in different gases, notably in nitrogen and argon, and not less remarkably in the more volatile compounds of the atmosphere. Paulsen thinks the auroral spectrum wholly due to cathodic rays. Without stopping to discuss that question, it is certain that changes in the character of the electric discharge produce definite changes in the spectra excited by them. It has long been known that in many spectra the rays which are inconspicuous with an uncondensed electric discharge become very pronounced when a Leyden jar is in the circuit. This used to be ascribed to a higher temperature in this condensed spark, though measurements of that temperature have not borne out the explanation. Schuster and Hemsalech have shown that these changes of spectra are in part due to the oscillatory character of the condenser discharge which may be enhanced by self induction, and the corresponding change of spectrum thereby made more pronounced. Lightning we should expect to resemble condensed discharge much more than aurora, but this is not borne out by the spectrum. Pickering's recent analysis of the spectrum of a flash obtained by photography shows, out of nineteen lines measured by him, only two which can be assigned with probability to nitrogen and oxygen, while three hydrogen rays most likely due to water are very con-

spicuous, and eleven may be reasonably ascribed to argon, krypton and xenon, one to more volatile gas of the neon class, and the brightest ray of all is but a very little less refrangible than the characteristic auroral ray, and coincides with a strong ray of calcium, but also lies between, and close to, an argon and a neon ray, neither of them weak rays. There may be some doubt about the identification of the spectral rays of auroras because of the wide limits of the probable errors in measuring wave-lengths so faint as most of them are, but there is no such doubt about the wave-lengths of the rays in solar protuberances measured by Deslandres and Hale. Stassano found that these rays, forty-four in number, lying between the Fraunhofer line F and 3148 in the ultra-violet, agree very closely with rays which Professor Liveing and myself measured in the spectra of the most volatile atmospheric gases. It will be remembered that one of the earliest suggestions as to the nature of solar prominences was that they were solar auroras. This supposition helped to explain the marvellous rapidity of their changes, and the apparent suspension of brilliant self-luminous clouds at enormous heights above the Sun's surface. Now the identification of the rays of their spectra with those of the most volatile gases, which also furnish many of the auroral rays, certainly supports that suggestion. A stronger support, however, seems to be given to it by the results obtained at the total eclipse of May, 1901, by the American expedition to Sumatra. In the *Astrophysical Journal* for June last is a list of 339 lines in the spectrum of the corona photographed by Humphreys, during totality, with a very large concave grating. Of these no fewer than 209 do not differ from lines we have measured in the most volatile gases of the atmosphere, or in krypton, or xenon, by more than one unit of wave length on Angström's scale, a quantity within the limit of probable error. Of the remainder, a good many agree to a like degree with argon lines, a very few with oxygen lines, and still fewer with nitrogen lines; the characteristic green auroral ray, which is not in the range of Humphreys' photographs, also agrees within a small fraction of a unit of wave-length with one of the rays emitted by the most volatile atmospheric gas. Taking into account the Fraunhofer lines H, K and G, usually ascribed to calcium, there remain only fifty-five lines of the 339 unaccounted for to the degree of probability indicated. Of these considerably more than half are very weak lines which have not depicted themselves on more than one of the six films exposed, and extended but a very short distance into the Sun's atmosphere. There are, however, seven which are

stronger lines, and reach to considerable height above the Sun's rim, and all have depicted themselves on at least four of the six films. If there be no considerable error in the wave lengths assigned (and such is not likely to be the case), these lines may perhaps be due to some volatile element which may yet be discovered in our atmosphere. However that may be, the very great number of close coincidences between the auroral rays and those which are emitted under electric excitement by gases of our atmosphere almost constrains us to believe, what is indeed most probable on other grounds, that the Sun's coronal atmosphere is composed of the same substances as the Earth's and that it is rendered luminous in the same way—namely, by electric discharges. This conclusion has plainly an important bearing on the explanation which should be given of the outburst of new stars and of the extraordinary and rapid changes in their spectra. Moreover, leaving on one side the question whether gases ever become luminous by the direct action of heat, apart from such transfers of energy as occur in chemical change and electric disturbance, it demands a revision of the theories which attribute more permanent differences between the spectra of different stars to differences of temperature, and a fuller consideration of the question whether they cannot with better reason be explained by differences in the electric conditions which prevail in the stellar atmosphere.

If we turn to the question what is the cause of the electric discharges which are generally believed to occasion auroras, but of which little more has hitherto been known than that they are connected with sunspots and solar eruptions, recent studies of electric discharges in high vacua, with which the names of Crookes, Röntgen, Lenard and J. J. Thompson will always be associated, have opened the way for Arrhenius to suggest a definite and rational answer. He points out that the frequent disturbances which we know to occur in the Sun must cause electric discharges in the Sun's atmosphere far exceeding any that occur in that of the Earth. These will be attended with an ionisation of the gases, and the negative ions will stream away through the outer atmosphere of the Sun into the interplanetary space, becoming, as Wilson has shown, nuclei of aggregation of condensable vapors and cosmic dust. The liquid and solid particles thus formed will be of various sizes; the larger will gravitate back to the Sun, while those with diameters less than one and a half thousandths of a millimetre, but nevertheless greater than a wave length of light, will, in accordance with Clerk-Maxwell's

electromagnetic theory, be driven away from the Sun by the incidence of the solar rays upon them, with velocities which may become enormous, until they meet other celestial bodies, or increase their dimensions by picking up more cosmic dust or diminish them by evaporation. The Earth will catch its share of such particles on the side which is turned towards the Sun, and its upper atmosphere will thereby become negatively electrified until the potential of the charge reaches such a point that a discharge occurs, which will be repeated as more charged particles reach the Earth. This theory not only accounts for the auroral discharges, and the coincidence of their times of greatest frequency with those of the maxima of sunspots, but also for the minor maxima and minima. The vernal and autumnal maxima occur when the line through the Earth and Sun has its greatest inclination to the solar equator, so that the Earth is more directly exposed to the region of maximum of sunspots, while the twenty-six days period corresponds closely with the period of rotation of that part of the solar surface where faculæ are most abundant. J. J. Thompson has pointed out, as a consequence of the Richardson observations, that negative ions will be constantly streaming from the Sun merely regarded as a hot body, but this is not inconsistent with the supposition that there will be an excess of this emission in eruptions, and from the regions of faculæ. Arrhenius' theory accounts also, in a way which seems the most satisfactory hitherto enunciated, for the appearances presented by comets. The solid parts of these objects absorb the Sun's rays, and as they approach the Sun become heated on the side turned towards him until the volatile substances frozen in or upon them are evaporated and diffused in the gaseous state in surrounding space, where they get cooled to the temperature of liquefaction and aggregated in drops about the negative ions. The larger of these drops gravitate towards the Sun and form clouds of the coma about the head, while the smaller are driven by the incidence of the Sun's light upon them away from the Sun and form the tail. The curvature of the tail depends, as Bredichin has shown, on the rate at which the particles are driven, which in turn depends on the size and specific gravity of the particles, and these will vary with the density of the vapor from which they are formed and the frequency of the negative ions which collect them. In any case Arrhenius' theory is a most suggestive one, not only with reference to auroras and comets, and the solar corona and chromosphere, but also as to the constitution of the photosphere itself.

THE STAR OF BETHLEHEM.

J. MORRISON, M. A., M. D., PH. D.

It will not, we presume, be out of place at this particular season of the year—a season marked by the approach of the anniversary of the first great festival of the Christian Church—to direct the attention of our readers to the consideration of a celestial phenomenon known in sacred history as the "Star of Bethlehem." This extraordinary apparition has been for many centuries, the subject of considerable discussion and speculation among Bible commentators, theologians, astronomers, mathematicians and others, many of whom were fully impressed with the conviction that the Star will again appear towards the close of the present century to announce another great crisis in the world's history, and accordingly astronomers are being constantly interrogated as to its nature and probable return.

So numerous indeed have these enquiries been of late years that the Director of one National Observatory caused a circular to be printed as a reply to all future enquiries on the matter. The discussion of this phenomenon naturally divides itself into two forms, viz., the *Astronomical* and the *Scriptural.*

While astronomers generally regard the apparition in question as one that transcends our knowledge of the physical sciences, and therefore not capable of an explanation from a scientific point of view, still a few of them have attempted to account for it on purely astronomical grounds.

Some have been disposed to regard it as a variable fixed star of long period and that it will therefore again appear. There is also a belief entertained in some quarters, that it may have been identical with the temporary or rather variable star which blazed forth in November, 1572, in the Constellation Cassiopœia.

This star was seen by the famous Danish astronomer Tycho Brahe, who described it as brighter than Jupiter, rivalling Venus in brilliancy, and visible in the day time. If such a star as this had appeared at or about the time of the birth of the Messiah, the historians and astronomers of that time would undoubtedly have left some record of it. On the other hand, some astronomers and Bible commentators have been of the opinion that the Star of Bethlehem was a conjunction of some of the bright planets—such as Jupiter and Venus or Saturn and Mars—and this theory is based on certain statements of the Jewish historian Josephus in the Second Book of his Antiquities, and also on the Rabbinical Commentaries of Abarbanel, Elieser and others on

the 24th Chapter of Numbers, from which it appears that three years and some months before the birth of Moses, that is in the year 1951 B. C., a remarkable conjunction of Jupiter and Saturn occurred in the Constellation Pisces, and as Moses was a prototype of the Messiah, a similar conjunction was said to have been predicted to occur three years before the birth of Christ. On computing backwards it is found that a conjunction of these planets did actually take place about these times, and it is assumed that the wise men were aware of this prediction, and accordingly came to Jerusalem, or rather Bethlehem, three years afterwards. Two or more planets are in conjunction when they are on the same meridian, and they may be apparently very close to each other so as to appear to the naked eye as one star, or they may be separated from each other by a very considerable angular distance, in which case they would attract very little or no attention. The conjunction lasts only for an instant, after which they would begin to separate, since they move with different angular velocities.

Now conjunctions of the planets are phenomena of tolerably frequent occurrrence; they are in fact, a necessary consequence of the order and arrangement of our solar system and possess no special significance. If three persons, for instance, travel in the same direction with different velocities in three concentric circles, and if they are in the same straight line at the time of starting, they must necessarily arrive some time or other at the same position again and again. This is exactly the case of planetary conjunctions, with the exception that the planets do not move in concentric circles, but in confocal ellipses. Any civil or physical commotion occurring simultaneously with a conjunction of any two or more planets, is simply an accidental coincidence and nothing more.

The most superficial perusal of the original record which is found in the second chapter of St. Matthew's Gospel, is sufficient to convince anyone that neither the sudden bursting forth of a variable fixed star nor the conjunction of any number of planets, is at all adequate to explain the phenomenon. The star conducted the Magi to Jerusalem and then disappeared; it must therefore have moved westward before the Magi, because they themselves came from some country east of Jerusalem, probably from Mesopotamia—the land of Melchizedek and Balaam—where the last dying embers of the Noetic Church still smouldered. The original record is Ἐν ἡμέραις Ἡρώδου τοῦ βασιλέως, ἰδοὺ, μάγοι ἀπὸ ἀνατολῶν παρεγένοντο εἰς Ἰεροσολυμα, . .

The object of their visit was to worship Him who was born King of the Jews, declaring, Εἴδομεν γὰρ αὐτοῦ τον ἀστέρα ἐν τῇ ἀνατολῇ.

Now if the star appeared to the Magi in the east and in the east only, it could never have conducted them to Jerusalem. We take the passage just quoted to mean that they saw the star when *they* themselves were in the east, and that the star guided them in their westward journey across the mountains and desert plains of what is now Northern Syria. On their arrival at Jerusalem they enquired about the new born Messiah, but no one could give them the desired information, nor does it appear that anyone there ever saw the star. This is the more remarkable because the Jews were at that very time anxiously waiting for the arrival among them of the long promised Messiah who, they imagined, would deliver them from the dominion of the Romans, and any unusual astronomical phenomenon such as that just alluded to, happening at that time, would certainly have been regarded by them as a sign from heaven, but no such sign appears to have been given to them; they were, in fact, in profound ignorance of the extraordinary event which had just occurred in their very midst. Nor were the Jews the only people who were then expecting a crisis in the temporal and spiritual affairs of the world. The Greeks and Romans, as we learn from the writings of their poets and philosophers, were also looking forward to the appearance of some great personage who would usher in a new and better state of things and deliver the race from the spiritual evils under which all nations were then groaning. Thus the poet Virgil writes:

> "Ultima Cumaei venit jam carminis aetas
> Magnus ab integro saeclorum nascitur ordo.
> Jam redit et Virgo, redeunt Saturnia regna;
> Jam nova progenies coelo demittitur alto.
> Tu modo nascenti puero, quo ferrea primum
> Desinet, ac toto surget gens aurea mundo,
> Casta, fave Lucina, tunc jam regnat Apollo,
> Ille deûm vitam accipiet, divisque videbit
> Permixtos heroas, et ipse videbitur illis;
> Pecatumque reget patriis virtutibus orbem."

The visit of these oriental philosophers to Jerusalem was a very interesting feature in the history of our Lord's birth into the world. It proves that a knowledge of ancient prophecy respecting the coming of the Messiah, had been preserved in countries far distant from the land of Israel, nor need we assume that the Magi derived their knowledge of the Lord's coming from the Jews or from the Jewish Scriptures, but from a more ancient and

more widely diffused revelation from which portions of our present Scriptures have been derived, some of the principles and facts of which were embodied in the mythologies of the nations of antiquity and traces of which are still found in almost every region of the globe.

When Herod heard of the mission of the Magi he was greatly disturbed and "all Jerusalem with him," and having learned from the "chief priests and scribes" that all the prophecies pointed to Bethlehem in Judea as the place in which the future "King of the Jews" should be born, he privately sent for the Magi and diligently enquired of them when the star appeared, and finally instructed them to proceed to Bethlehem to search for the "young child," with the command that when they shall have found him they return and inform him. Just as they were about to set out on this mission, "Ἰδου, ὁ ἀστὴρ ὃν εἶδον ἐν τῇ ἀνατολῇ προῆγεν αὐτοὺς ἕως ἐλθων ἔστη ἐπάνω οὗ ἦν τὸ παιδίον."

This positive statement at once establishes its character. No ordinary astronomical apparition could fulfill the conditions here imposed. A fixed star or planets in conjunction would rise in the east, pass across the sky in their apparent diurnal course and descend below the western horizon; but here was an apparition which in its westward course, conducted the Magi to Jerusalem, disappeared for a day or two and then reappeared, and instead of pursuing a westerly course, moved almost due south to Bethlehem.

It is evident, too, that in order to point out the very house by standing directly over it, it could not have been a great height above the Earth's surface, in fact it must have been quite low down in the atmosphere. The circumstances of the motion of this extraordinary object are such as cannot be explained by astronomy or any of the other physical sciences. The reappearance of the star at the time when its encouragement and direction were most needed, proves that it was not a natural but a supernatural phenomenon sent for a special purpose and to the wise men only, for no others on Earth, so far as appears from the gospel record, ever beheld it but the Magi, whose spiritual discernment enabled them to interpret its significance.

The wise men among the Gentiles and the shepherds among the Jews, were the only persons who received any outward intimation of the Lord's birth, and the only ones who came to salute Him at His coming. The shepherds were directed by the audible voice of the angels, the Magi by the silent language of the star, the one by hearing, the other by sight.

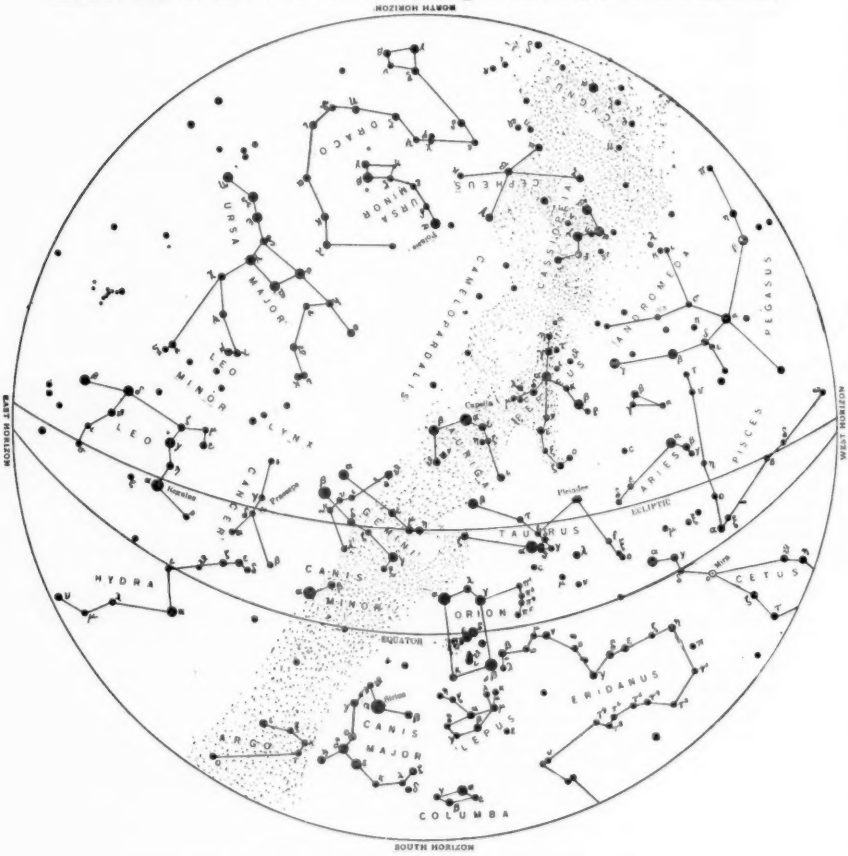
From a human point of view an advantage would have resulted from the Magi being led directly to the Lord's birthplace. The jealousy and wrath of Herod would not have been excited and the innocents of Bethlehem would have been spared, but here we must acknowledge the hand of an over-ruling Providence whose ways transcend all human ideas and experience.

[TO BE CONCLUDED.]

PLANET NOTES FOR FEBRUARY.

H. C. WILSON.

Mercury will be at inferior conjunction Feb. 2 and at greatest elongation west from the Sun, 26° 59′, Feb. 27 and so will be visible as morning star during the last week of the month. On the morning of Feb. 13, while hidden in the



THE CONSTELLATIONS AT 9 P. M. FEBRUARY 1, 1903.

glare of the Sun, Mercury will be in conjunction with Saturn, the former being then three degrees north of the latter.

Venus is now evening star, setting in the southwest a little over an hour after sunset. She is on the farther side of her orbit from the Earth and so near her minimum brilliancy although the disk is nearly full. During the month the planet

will emerge slowly from the twilight but her real brightness will change very little. She will move quite rapidly northward so that at the end of the month she will be seen almost due west in the early evening.

Mars is to be seen after midnight, and reaches the meridian about four o'clock in the morning. The apparent diameter of the disk of the planet is now about 11″, so that the more prominent markings of its surface can be readily seen. In some of the late numbers of the astronomical magazines there have been articles on some experiments which go to show that the so-called "canals" of Mars may be purely optical effects.

Jupiter will be at conjunction with the Sun Feb. 19 and therefore will be practically invisible during the month.

Saturn having just passed conjunction will also be invislble during this month.

Uranus is morning star, but as yet in very unfavorable position for observation.

Neptune is the only planet which is now in good position to be observed in the evening, and it, having so small a disk even in large telescopes, is of very little interest to the amateur. It is to be found Feb. 1 about 14′ south and 3^m 20^s west from the star η Geminorum. It will move a little to the west each day, so that on March 1 it will be 4^m 59^s west of the star. Its motion in declination is very slight.

The Moon.

		Phases.	Rises. (Central Standard Time at Northfield; Local Time 13m less.)	Sets.
			h m	h m
Feb.	4-5	First Quarter	10 45 A. M.	12 59 A. M.
	11-12	Full Moon	5 37 P. M.	7 21 "
	19	Last Quarter.	1 25 A. M.	11 20 "
	27	New Moon	6 47 "	6 32 P. M.

Occultations Visible at Washington.

Date. 1903.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
Feb. 2	B.A.C. 221	5.7	3 54	56	5 19	250	1 25
7	W.B.(2), V, 606	7.0	4 43	63	5 50	282	1 07
7	119 Tauri	4.6	6 34	21	7 08	329	0 34
7	120 Tauri	5.3	7 03	47	8 05	306	1 02
8	20 Geminorum	6.3	4 58	100	6 03	257	1 05
8	21 Geminorum	6.5	4 58	89	6 03	258	1 05
8	26 Geminorum	5.0	10 21	102	11 37	277	1 16
10	B.A.C. 2872	6.8	4 12	110	5 03	265	0 51
10	A^1 Cancri	5.6	8 37	152	9 26	236	0 49
10	60 Cancri	5.7	15 38	139	16 30	260	0 52
14	B.A.C. 4200	5.7	8 47	165	9 19	235	0 32

COMET AND ASTEROID NOTES.

New Comet *a*, 1903 (Giacobini).—A new comet was discovered by Giacobini at Nice January 15. It was observed at Nice Jan. 19.2498 Gr. M. T. in R. A. 22^h 57^m $48^s.0$, Decl. + 2° 16′ 24″. It was then moving eastward 17′ and northward 12′ daily.

The following elements and ephemeris were received by cable from Kiel, Germany, by the courtesy of Harvard College Observatory, Jan. 25:

ELEMENTS OF COMET *a* 1903.

$T = 1903$ March 14.34 Greenwich M. T.
$\omega = 133°\ 37'$
$\Omega = 2\ 32$
$i = 30\ 30$
$q = 0.4085$

EPHEMERIS OF COMET *a* 1903.

	R. A. h m s	Decl. ° ′	Brightness.
Jan. 25.5	23 04 36	+3 48	1.46
29.5	23 09 24	+4 52	
Feb. 2.5	23 14 40	+6 00	
6.5	23 20 20	+7 12	2.64

The comet was looked up here with the 16-inch telescope on Jan. 22 and was found to be a small one, about one minute of arc in diameter, nearly round and with no distinct nucleus. The seeing was poor at the time and the position was not determined. The comet was then barely visible in the five-inch finder, but according to the above ephemeris its brightness will increase rapidly so that it should become easily visible in small telescopes. It is to be found toward the southwest in the evening, as soon as darkness comes on, in the region south of the great Square of Pegasus, really in the western part of Pisces.

Elements of Comet *b*, 1902 (Perrine).—*Bulletin No. 1*, of the Laws Observatory, University of Missouri, contains observations and elements of Comet *b*, 1902 (Perrine), by F. H. Seares. The observations extend from Sept. 4 to Oct. 28 and the elements depend upon three normal places, using observations made at Berlin, Heidelberg and Jena on Sept. 2, and at the Laws Observatory Sept. 26, 27, 28, 30 and Oct. 24, 25, 26, 28. The three normal places are represented very exactly by the following elements:

ELEMENTS OF COMET *b*, 1902.

$T = 1902$ Nov. 23.90094 Berlin M. T.
$\omega = 154°\ 01'\ 34''.4$
$\Omega = 49\ 20\ 11\ .0$ 1902.0 $\log q = 9.602596$
$i = 156\ 20\ 56\ .1$ $\log e = 9.999709$

The writer discusses some adaptations of Leuschner's formulæ which render his method very convenient of use when the time intervals are large.

The rectangular heliocentric coördinates from the above elements are given by the equations

$$\left.\begin{aligned} x &= [9.978890]\, r \sin (196°\ 10'\ 25''.4 + v) \\ y &= [9.996590]\, r \sin (288\ 28\ 38\ .5 + v) \\ z &= [9.517149]\, r \sin (219\ 38\ 46\ .0 + v) \end{aligned}\right\} 1903.0$$

Comet *d*, 1902 (Giacobini).—The best elements of this comet which have come to hand are those of F. Ristenpart in *A. N.* 3838.

$T = 1903$ March 25.32785
$\omega = 6°\ 33'\ 43''.1$
$\Omega = 117\ 26\ 47\ .3$ 1903.0
$i = 43\ 51\ 02\ .1$
$\log q = 0.440250$

An observation by Barnard Dec. 30 is represented very closely by these elements. The equatorial coördinates may be obtained by

$$x = [0.337152] \sin (v + 222^\circ\ 19'\ 25''.8) \sec^2 \tfrac{1}{2} v$$
$$y = [0.440243] \sin (v + 132\ \ 03\ \ 31\ \ .5) \sec^2 \tfrac{1}{2} v$$
$$z = [0.229005] \sin (v + \ 41\ \ 37\ \ 20\ \ .6) \sec^2 \tfrac{1}{2} v.$$

Ristenpart's ephemeris extends only to Feb. 1 but the following ephemeris has been computed from the same equations:

EPHEMERIS OF COMET *d*, 1902.

Berlin Midn.	R. A.	Decl.	log *r*.	log Δ.
	h m s	° ′ ″		
Feb. 1	6 41 31.0	+ 13 58 24	0.4483	0.2852
5	39 42.8	13 18 04	0.4471	0.2898
9	38 16.1	15 36 22	0.4460	0.2954
13	37 12.7	17 52 55	0.4450	0.3017
17	36 33.7	19 07 14	0.4441	0.3088
21	36 20.4	20 19 03	0.4433	0.3165
25	36 33.3	21 28 08	0.4426	0.3248
Mar. 1	37 12.8	22 34 17	0.4420	0.3334
5	6 38 19.1	+ 23 37 25	0.4414	0.3424

Comet *d*, 1902 (Giacobini).—My first view of Comet *d* was obtained on 1902, December 23 with the ten-inch telescope. The comet was then small and almost round, with a central condensation, but no distinct nucleus or train. Its brightness was about equal to that of an eleventh magnitude star. On January 18 I picked the comet up easily by means of a rough extension of the ephemeris published by Morgan and Frederick, but it had not changed appreciably either in appearance or brightness since the first observation. ZACCHEUS DANIEL.

BUCKNELL UNIVERSITY, Lewisburg, Penn.,
1903, January 20.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discoverer.	Place.	Local M. T.	R. A.	Decl.	Mag.
			h m	h m s	° ′ ″	
1902	KU Charlois	Nice	Dec. 2 9 08.8	3 44 45.3	+ 10 15 02	11
	KV Wolf	Heidelberg	23 7 40.5	3 00.6	+ 20 05	13
	KW "	"	24 9 56.4	6 49.3	+ 20 15	14.5
	KX "	"	9 56.4	6 59.6	+ 21 35	12.5
	KY "	"	12 20.3	7 41.9	+ 31 58	13.8
	KZ "	"	12 20.3	7 40.0	+ 30 48	13.2

Numbering of Asteroids.—The following permanent numbers have been assigned to asteroids discovered during the past two years:

Designation.	Discovered By.	Place.	Date.
(480) 1901 GL	Wolf and Carnera	Heidelberg	May 21, 1901
(481) 1902 HP	Carnera	"	Feb. 12, 1902
(482) 1902 HT	Wolf	"	Mar. 3, 1902
(483) 1902 HU	Wolf	"	Mar. 4, 1902
(484) 1902 HX	Wolf	"	April, 29, 1902
(485) 1902 HZ	Carnera	"	May 7, 1902
(486) 1902 JB	Carnera	"	May 11, 1902
(487) 1902 JL	Carnera	"	July 9, 1902

The last, (487), has been named Venetia. 1901 HL was found to be identical with (358) Apollonia; 1902 HO with (458); 1902 HQ with (93) Minerva; 1902 HS with (359) Georgia; 1902 HV with (72) Feronia; 1902 JH with JB = (486); 1902 JJ with (451) Patentia and 1902 JN with (311) Claudia.

Those designated 1901 HM, 1902 HR, HW, HY, JA, 1900 JC, 1902 JD 1899 JF, 1902 JG, JK and JM were insufficiently observed to determine elliptic orbits; JK is perhaps identical with (470) Kilia, and JE is to be stricken out.

Elements of Asteroid (478) Tergeste.—In *A. N.* 3838 Mr. S. de Mello e Simas gives elements depending on seventeen observations of this planet the first and last dates being Sept. 21 and Dec. 7, 1901.

ELEMENTS OF ASTEROID (478).

Epoch 1901 Oct. 22.0 Berlin M. T.

$M = 267°\ 18'\ 16''.0$
$\omega = 240\ 46\ 32\ .4$
$\Omega = 234\ 41\ 15\ .9$ 1901.0
$i = 13\ 09\ 39\ .4$
$\phi = 4°\ 57'\ 31''.2$
$\mu = 677''.659$
$\log a = 0.479331$

An ephemeris is given for the opposition of the planet for this winter, extending from Dec. 20, 1902 to Mar. 10, 1903. The portion for February and March follows. The magnitude of the planet at opposition Jan. 3 is given as 11.0.

EPHEMERIS OF PLANET (478).

Berlin 12^h	R. A.	Decl.	log r.	log Δ.
	h m s	° ′		
Feb. 2	6 27 30	+ 7 39.1		
4	26 38	7 42.4		
6	25 52	7 46.0	0.4402	0.2898
8	25 12	7 49.9		
10	24 38	7 54.0		
12	24 11	7 58.4		
14	23 50	8 03.0	0.4401	0.3057
16	23 35	8 07.9		
18	23 27	8 12.8		
20	23 25	8 17.9		
22	23 30	8 23.1	0.4401	0.3232
24	23 41	8 28.4		
26	23 58	8 33.7		
28	24 21	8 39.2		
Mar. 2	24 50	8 44.6	0.4401	0.3415
4	25 25	8 49.8		
6	26 06	8 55.1		
8	26 53	9 00.5		
10	6 27 45	+ 9 06.0	0.4401	0.3601

VARIABLE STARS.

The Variable Star U Geminorum.—This star has just passed a maximum. After a week's cloudy weather, I found it bright on January 18. The following are the observations I have obtained thus far with the 10-inch refractor The magnitudes are on the photometric scale published by J. A. Parkhurst in the *Astronomical Journal* No. 523.

1903, Jan. 10.542, G. M. T., $U < b = < 11^m.61$ moon
18.691 $U = b = 9\ .34$ fair
19.538 $b\,1.5\,U = 9\ .49$ fair

ZACCHEUS DANIEL.

BUCKNELL UNIVERSITY, Lewisburg, Penn.,
1903, January 21.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.]

U Cephei.

	d	h
Feb.	1	3
	3	15
	6	2
	8	14
	11	2
	13	14
	16	2
	18	14
	21	1
	23	13
	26	1
	28	13

Z Persei

Feb.	1	18
	4	19
	7	21
	10	22
	13	23
	17	1
	20	2
	23	3
	26	5

Algol.

Feb.	2	20
	5	17
	7	14
	11	11
	14	8
	17	4
	20	1
	22	22
	25	19
	28	16

λ Tauri.

Feb.	1	2
	5	1
	9	0
	12	23
	16	22
	20	20
	24	19
	28	18

R Canis Majoris

Feb.	2	1
	3	5
	4	8
	5	11
	6	15
	7	18
	8	21
	10	1
	11	4

R Can. Maj.

	d	h
Feb.	12	7
	13	10
	14	14
	15	17
	16	20
	17	23
	19	3
	20	6
	21	9
	22	12
	23	16
	24	19
	25	22
	27	2
	28	5

S Cancri.

Feb.	2	0
	11	12
	21	0

S Antliæ.

Period $7^h\ 46^m.8$

Feb.	1	4
	2	4
	3	3
	4	2
	5	2
	6	1
	7	0
	8	0
	8	23
	9	22
	10	22
	11	21
	12	20
	13	20
	14	19
	15	18
	16	18
	17	17
	18	16
	19	16
	20	15
	21	14
	22	14
	23	13
	24	12
	25	12
	26	11
	27	10
	28	10

δ Librae.

Feb.	1	18
	4	2

δ Librae.

	d	h
Feb.	6	10
	8	18
	11	2
	13	9
	15	17
	18	1
	20	9
	22	17
	25	1
	27	9

U Coronæ.

Feb.	1	15
	5	2
	8	13
	12	0
	15	11
	18	21
	22	8
	25	19

U Ophiuchi.

Feb.	1	20
	2	16
	3	12
	4	8
	5	4
	6	0
	6	21
	7	17
	8	13
	9	9
	10	5
	11	1
	11	21
	12	18
	13	14
	14	10
	15	6
	16	2
	16	22
	17	18
	18	14
	19	11
	20	7
	21	3
	21	23
	22	19
	23	15
	24	11
	25	8
	26	4
	27	0
	27	20
	28	16

Z Herculis.

Feb.	1	5
	3	7

Z Herculis.

	d	h
Feb.	5	5
	7	7
	9	5
	11	7
	13	5
	15	7
	17	5
	19	7
	21	5
	23	6
	25	4
	27	6

RS (S^2) Sagittarii.

Feb.	3	7
	5	17
	8	3
	10	13
	12	23
	15	9
	17	19
	20	5
	22	15
	25	1
	27	11

RX (X^2) Herculis.

Feb.	1	7
	2	4
	3	1
	3	23
	4	20
	5	17
	6	15
	7	12
	8	9
	9	7
	10	4
	11	1
	11	23
	12	20
	13	17
	14	15
	15	12
	16	9
	17	7
	18	4
	19	1
	19	23
	20	20
	21	17
	22	15
	23	12
	24	9

RX (X^2) Her.

	d	h
Feb.	25	7
	26	4
	27	2
	27	23
	28	20

RV (V^2) Lyrae.

Feb.	2	3
	5	18
	9	8
	12	22
	16	13
	20	3
	23	18
	27	8

U Sagittae.

Feb.	1	4
	4	13
	7	22
	11	7
	14	17
	18	2
	21	11
	24	20
	28	5

SY (X^3) Cygni.

Feb.	6	15
	12	15
	18	16
	24	16

SW (V^3) Cygni.

Feb.	4	6
	8	20
	13	10
	18	0
	22	13
	27	3

UW (Z^4) Cygni.

Feb.	4	2
	7	13
	11	0
	14	10
	17	21
	21	8
	24	19
	28	6

W Delphini.

Feb.	4	22
	9	17
	14	13
	19	8
	24	3
	28	23

Minima of Variable Stars of the Algol Type.—Continued.

Y Cygni.		Y Cygni.		Y Cygni.		Y Cygni.		Y Cygni.	
d	h	d	h	d	h	d	h	d	h
Feb. 1	20	Feb. 7	20	Feb. 13	20	Feb. 19	19	Feb. 25	19
3	4	9	4	15	4	21	3	27	3
4	20	10	20	16	20	22	19	28	19
6	4	12	4	18	3	24	3		

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.			Minimum.		Maximum.	
		h		h			h		h
SU Cygni	Feb. 1	22	Feb. 3	6	Y Sagittarii	Feb. 14	13	Feb. 16	8
X Cygni	2	22	9	17	U Vulpeculæ	15	18	17	21
Y Sagittarii	3	0	4	19	T Monocerotis	17	4	25	2
δ Cephei	3	4	4	19	SU Cygni	17	7	18	15
ζ Geminorum	3	15	8	15	T Vulpeculae	18	16	20	1
T Vulpeculæ	5	8	6	17	RV Scorpii	18	20	20	6
SU Cygni	5	18	7	0	β Lyræ	19	5	22	7
SZ Cygni	.....		7	23	δ Cephei	19	7	20	22
W Geminorum	6	6	8	21	X Cygni	19	8	26	3
β Lyræ	6	7	9	9	Y Sagittarii	20	7	22	2
W Sagittarii	6	17	9	17	U Aquilae	20	23	23	3
RV Scorpii	6	17	8	3	U Sagittarii	21	0	24	0
U Aquilae	6	22	9	2	SU Cygni	21	3	22	11
Y Ophiuchi	7	4	13	9	X Sagittarii	21	12	24	9
X Sagittarii	7	11	10	8	W Geminorum	21	18	24	9
U Sagittarii	7	12	10	12	W Sagittarii	21	21	24	21
U Vulpeculæ	7	19	9	22	SZ Cygni	.....		23	1
δ Cephei	8	13	10	4	T Vulpeculæ	23	2	24	11
Y Sagittarii	8	18	10	13	TX Cygni	23	17	28	20
W Virginis	8	18	16	23	U Vulpeculae	23	18	25	21
TX Cygni	9	0	14	3	Y Ophiuchi	24	7	30	12
SU Cygni	9	14	10	22	δ Cephei	24	15	26	6
T Vulpeculæ	9	19	11	4	RV Scorpii	24	21	26	7
β Lyræ	12	18	16	1	SU Cygni	25	0	26	8
RV Scorpii	12	18	14	4	β Lyræ	25	16	28	23
SU Cygni	13	10	14	18	W Virginis	26	1	34	6
δ Cephei	13	22	15	13	Y Sagittarii	26	2	27	21
U Aquilae	13	23	16	3	T Vulpeculae	27	13	28	22
T Vulpeculæ	14	5	15	14	U Sagittarii	27	18	30	18
W Geminorum	14	0	16	15	U Aquilae	28	0	30	4
U Sagittarii	14	6	17	6	X Sagittarii	28	12	31	9
W Sagittarii	14	7	17	7	SU Cygni	28	20	30	4
X Sagittarii	14	11	17	8					

Maxima of UY Cygni.

Period $13^h\ 26^m.3$. The minimum takes $1^h\ 55^m$ before the maximum.

	h		h		h		h
Feb. 1	16	Feb. 8	9	Feb. 15	2	Feb. 21	20
2	19	9	12	16	5	22	23
3	22	10	15	17	8	24	2
5	1	11	18	18	11	25	4
6	3	12	21	19	14	26	7
7	6	14	0	20	17	27	10
						28	13

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	d	h		d	h		d	h		d	h
Feb.	1	3	Feb.	8	1	Feb.	15	0	Feb.	22	3
	2	1		9	0		16	3		23	1
	3	0		10	3		17	1		24	0
	4	3		11	1		18	0		25	3
	5	1		12	0		19	3		26	1
	6	0		13	3		20	1		27	0
	7	3		14	1		21	0		28	3

Approximate Magnitudes of Variable Stars Dec. 10, 1902.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
T Androm.	0 17.2	+ 26 26	13 *d*	R Camelop.	14 25.1	+ 84 17	9 *i*
T Cassiop.	0 17.8	+ 55 14	9 *d*	R Bootis	14 32.8	+ 27 10	8 *i*
R Androm.	0 18.8	+ 38 1	6 *i*	S Librae	15 15.6	− 20 2	*u*
S Ceti	0 19.0	− 9 53	10 *d*	S Serpentis	15 17.0	+ 14 40	*f*
W Cassiop.	0 49.0	+ 58 1	*u*	S Coronae	15 17.3	+ 31 44	10 *i*
S "	1 12.3	+ 72 5	14 *i*	S Ursae Min.	15 33.4	+ 78 58	7
R Piscium	1 25.5	+ 2 22	10 *d*	R Coronae	15 44.4	+ 28 28	6
R Trianguli	1 31.0	+ 33 50	*u*	V "	15 45.9	+ 39 52	*u*
U Persei	1 52.9	+ 54 20	*u*	R Serpentis	15 46.1	+ 15 26	*u*
R Arietis	2 10.4	+ 24 36	8 *d*	R Herculis	16 1.7	+ 18 38	9
o Ceti	2 14.3	− 3 26	9 *i*	R Scorpii	16 11.7	− 22 42	*s*
S Persei	2 15.7	+ 58 8	9 *i*	S "	16 11.7	− 22 39	*s*
R Ceti	2 20.9	− 0 38	12 *d*	U Herculis	16 21.4	+ 19 7	8 *i*
U "	2 28.9	− 13 35	8 *i*	R Ursae Min.	16 31.3	+ 72 28	10
R Persei	3 23.7	+ 35 20	*u*	W Herculis	16 31.7	+ 37 32	*f*
R Tauri	4 22.8	+ 9 56	12 *i*	R Draconis	16 32.4	+ 66 58	9 *d*
S "	4 23.7	+ 9 44	13 *i*	S Herculis	16 47.4	+ 15 7	8 *i*
R Aurigae	5 9.2	+ 53 28	8 *i*	R Ophiuchi	17 2.0	− 15 58	*s*
U Orionis	5 49.9	+ 20 10	12 *d*	T Herculis	18 5.3	+ 31 0	8 *i*
R Lyncis	6 53.0	+ 55 28	10 *d*	R Scuti	18 42.2	− 5 49	*s*
R Geminorum	7 1.3	+ 22 52	8 *d*	R Aquilae	19 1.6	+ 8 5	*s*
S Canis Min.	7 27.3	+ 8 32	9 *i*	R Sagittarii	19 10.8	− 19 29	*s*
R Cancri	8 11.0	+ 12 2	9 *d*	S "	19 13.6	− 19 12	*s*
V "	8 16.0	+ 17 36	11 *d*	R Cygni	19 34.1	+ 49 58	12 *d*
S Hydrae	8 48.4	+ 3 27	12 *d*	RT Cygni	19 40.8	+ 48 32	*u*
T "	8 50.8	− 8 46	*f*	X "	19 46.7	+ 32 40	9 *d*
R Leonis Min.	9 39.6	+ 34 58	9 *d*	S "	20 3.4	+ 57 42	14 *d*
R Leonis	9 42.2	+ 11 54	8 *d*	RS "	20 9.8	+ 38 28	7 *d*
R Ursae Maj.	10 37.6	+ 69 18	9 *d*	R Delphini	20 10.1	+ 8 47	8 *i*
R Comae	11 59.1	+ 19 20	*u*	U Cygni	20 16.5	+ 47 35	8
T Virginis	12 9.5	− 5 29	*u*	V "	20 38.1	+ 47 47	13 *i*
R Corvi	12 14.4	− 18 42	11	T Aquarii	20 44.7	− 5 31	7 *i*
Y Virginis	12 28.7	− 3 52	10	R Vulpeculae	20 59.9	+ 23 26	11 *d*
T Ursae Maj.	12 31.8	+ 60 2	8 *i*	T Cephei	21 8.2	+ 68 5	7 *i*
R Virginis	12 33.4	+ 7 32	8 *d*	S "	21 36.5	+ 78 10	8 *d*
S Ursae Maj.	12 39.6	+ 61 38	9 *i*	S Lacertae	22 24 6	+ 39 48	*u*
U Virginis	12 46.0	+ 6 6	*u*	R "	22 38.8	+ 41 51	*u*
V "	13 22.6	− 2 39	*u*	S Aquarii	22 51.8	− 20 53	10 *d*
R Hydrae	13 24.2	− 22 46	*u*	R Pegasi	23 1.6	+ 10 0	11 *d*
S Virginis	13 27.8	− 6 41	10	S "	23 15.5	+ 8 22	9 *i*
R Canes Ven.	13 44.6	+ 40 2	11 *d*	R Aquarii	23 38.6	− 15 50	7 *i*
S Bootis	14 19.5	+ 54 16	12 *i*	R Cassiopeiae	23 53.3	+ 50 50	8 *d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Approximate Data for 1903.0 of Short Period Variable Stars.

	Star.	R. A. h m s	Decl. ° ′	Algol Type.	Approx. Period. d h m	Magnitudes. Max.	Min.
320	U Cephei	0 53 39	+ 81 21.2	A	2 11 49.5	7.1	9.2
922	Z Persei	2 33 52	+ 41 46.9	A	3 01 21.5	9.4	12
1090	Algol	3 01 51	+ 40 35.0	A	3 22 52	2.3	3.5
1411	λ Tauri	3 55 18	+ 12 13.0	A	3 22 52	3.4	4.2
2279	T Monocer.	6 19 59	+ 7 08.4		27 0	6	8
2335	W Geminorum	6 29 24	+ 15 24.4		7 18	7	8
2509	ζ Geminorum	6 58 22	+ 20 42.8		10 3	3.7	4.5
2610	R Canis Maj.	7 15 5	− 16 12.7	A	1 3 16	5.9	6.7

Approximate Data for Short Period Variable Stars.—Continued.

Star.	R. A. h m s	Decl. ° ′	Algol Type.	Approx. Period. d h m	Magnitude. Max.	Min.
2781 (R^2) RR Puppis	7 43 37	−41 08.3	A	5 10 20	9 +	10 +
2852 V Puppis	7 55 27	−48 58.9	A	1 10 54.4	4.4	5.2
3040 V Carinæ	8 26 45	−59 47.9		6 17	7.2	8.0
3087 T Velorum	8 34 32	−47 01.3		9 6	7.5	8.5
3109 S Cancri	8 38 24	+19 23.0	A	9 11 38	8.2	9.8
3355 W Carinæ	9 19 20	−55 32.7		8 18	7.5	8.5
3407 S Antliæ	9 28 04	−28 12.0	A	0 7 46.8	6.7	7.3
3416 S Velorum	9 29 34	−44 46.7	A	5 22 24.3	7.8	9.3
4364 S Muscæ	12 07 34	−69 36.7		9 16	6.5	7.3
4415 T Crucis	12 16 03	−61 44.6		6 17.5	6.8	7.6
4429 R Crucis	12 18 18	−61 05.5		11 15.5	6.8	8.0
4611 S Crucis	12 48 38	−57 54.2		9 9	6.6	7.8
4805 W Virginis	13 21 02	− 2 52.5		17 6.5	9	10
5192 V Centauri	14 25 36	−56 27.5		11 0	6.7	7.6
5374 δ Libræ	14 55 48	− 8 8.0	A	2 7 51	5.0	6.2
5484 U Coronæ	15 14 14	+32 00.1	A	3 10 51	7.5	8.9
5713 S Trian. Austr.	15 52 28	−63 30.0		12 15.5	6.5	7.5
5823 S Normæ	16 10 49	−57 39.6		9 18	6.5	7.4
5949 R Aræ	16 31 41	−56 48.0	A	4 10 12.1	6.9	8.0
6071 (V^2) RV Scorpii	16 51 59	−33 27.5		12 3	6.8	7.6
6189 U Ophiuchi	17 11 36	+ 1 19.1	A	0 20 08	6.0	6.7
6368 X Sagitarii	17 41 27	−27 47.6		7 0.2	4	6
6404 Y Ophiuchi	17 47 27	− 6 07.2		17 3	6.2	7.2
6442 Z Herculis	17 53 44	+15 08.4	A	1 22 29 3 23 50	7.1	8.0
6472 W Sagittarii	17 58 50	−29 35.2		7 14	4.8	5.8
6546 (S^2) RS Sagittarii	18 11 10	−34 08.5	A	2 9 58.6	6.4	7.5
6573 Y Sagittarii	18 15 41	−18 54.2		5 18.5	5.8	6.6
6663*a* (X^2) RX Herculis	18 26 09	+12 32.7	A	0 21 20.5	7	7.8
6663 U Sagittarii	18 26 10	−19 11.8		13 12	7.0	8.3
6758 β Lyrae	18 46 30	+33 15.0		6 11 12 22	3.4	4.5
6760 κ Pavonis	18 46 57	−67 21.3		9 2	4.0	5.5
6915 (V^2) RV Lyræ	19 12 38	+32 15.0	A	3 14 22.4	11	13
6927 U Sagittæ	19 14 34	+19 26.0	A	3 9 08.2	6.7	9
6984 U Aquilae	19 24 08	− 7 14.6		7 0.5	6.4	7.1
7034 U Vulpeculae	19 32 23	+20 07.0		8 0.3	7	7-8
7085*a* (T^3) SU Cygni	19 40 56	+29 01.8		7 17	6-7	7-8
7096 (X^3) SY Cygni	19 42 50	+32 28.0	A	6 0 09	10	<12
7124 η Aquilae	19 47 32	+ 0 45.4		7 4	3.5	4.7
7149 S Sagittae	19 51 36	+16 22.6		8 9	5.6	6.4
7223 (V^3) SW Cygni	20 03 55	+46 01.1	A	4 13 45	8-9	11-12
7318 (Z^4) UW Cygni	20 19 43	+42 55.5	A	3 10 49.2	10-11	13
7378 (Y^3) SZ Cygni	20 29 44	+46 16.2		15 2	8	9-10
7399 W Delphini	20 33 15	+17 56.5	A	4 19 21	9.5	<12
7437 X Cygni	20 39 36	+35 14.1		16 9 14	6.4	7.5
7483 T Vulpeculae	20 47 22	+27 53.0		4 10.5	5.5	6.5
7488 Y Cygni	20 48 12	+34 17.6	A	1 15 44 2 23 54	7.1	7.9
7514 (S^5) UY Cygni	20 52 24	+30 03.5		0 13 26.3	9-10	10-11
7539 (U^4) TX Cygni	20 56 32	+42 13.1		14 17.5	8-9	10
8073 δ Cephei	22 25 34	+57 55.1		5 9	3.7	4.9
8598 U Pegasi	23 53 02	+15 24.9		0 4 29.3	9.0	9.7

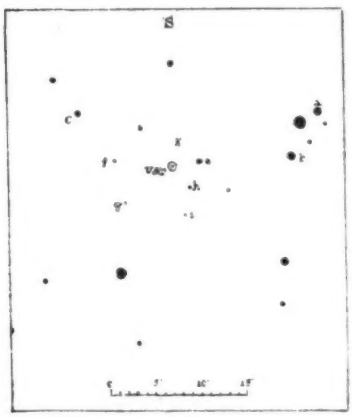
The stars marked A are of the Algol type. The designations in parentheses in the second column (R^2), (S^2), etc., are those of the *Annuaire du Bureau des Longitude* and the *Companion to the Observatory*. Those which follow them are the designations adopted by the Committee on Catalogue of Variable Stars of the *Astronomische Gesellschaft*.

Observed Minima of Algol-Type Variables.—The following are abstracted from a paper by Mr. Paul S. Yendell in *A. J.* 528, embodying some of the results of his observations from April to December 1902, at Dorchester, Mass.:

Star.		Local M. T. of Minimum. By Single Curve		By Equal Brightness.		Minimum Magnitude.	No. of Obs.
			h m	h	m		
320 U Cephei	Aug.	2	13 17	13	16	9.14	26
	Sept.	11	10 36	10	32	9.08	31
	Oct.	16	7 25	7	54	9.08	11
1090 Algol	Nov.	2	9 25	9	30	3.71	12
1411 λ Tauri	Oct.	28	11 34	11	25	4.36	9
	Nov.	1	10 52	10	57	...	12
5374 δ Libræ	May	9	10 01	10	08	6.25	12
6179 U Ophiuchi	May	9	11 48	11	45	6.81	10
	May	30	10 56	10	51	6.59	16
	June	9	12 18	12	15	6.65	9
	July	11	10 07	10	08	6.65	7
	Aug.	22	8 45	8	42	6.70	7
6927 U Sagittæ	Sept.	11	11 7	11	18	9.12	34

New Variable Star 17.1902 Lyræ.—In *A. N.* 3833 Mr. A. Stanley Williams gives an account of the discovery of this star. Its position is

R. A. $18^h\ 40^m\ 45^s.1$; Decl. $+ 43°\ 29'.2$ (1855).



New Variable 17.1902 Lyræ.

The accompanying diagram shows its position relative to the neighboring stars. The two brightest stars shown in the diagram are BD $+ 43°3058$ and 3072 given as 7.3^m and 7.0^m respectively. The star was found upon a number of photographic plates taken during 1899 and 1900. In 1901, Sept. and Nov., it was invisible on five plates and must have been below the 12th magnitude. The star has been frequently looked for during the year 1902, between Aug. 15 and Oct. 26, but it has always been invisible in a 6½-inch reflector, so that it must have been below the 12½ mag. during that period. Mr. Williams says that the period is evidently long and the range of variation considerable, though it is impossible at present to state anything definite with regard to these questions. The observations of 1900, however, indicate a pretty well defined maximum for Oct. 6, the photographic magnitude being 8.97. He gives the following list of comparison stars:

$a = 8^m.58$	$f = 10^m.87$
$b = 9\ .00$	$g = 11\ .12$
$c = 9\ .37$	$h = 11\ .32$
$d^* = 9\ .86$	$i = 11\ .55$
$e = 10\ .47$	$k = 12\ .16$

* The star *d* is just outside the diagram. It is BD $+ 43°.3053$ ($9^m.5$).

New Variable Star 20.1902 Cygni.—In *A. N.* 3833 Professor W. Ceraski announces a new variable star of the Algol type, discovered by Mme. L.

Ceraski in examining the photographs taken by M. S. Blajko, at Moscow. Its position is

R. A. $21^h\ 00^m\ 44^s.6$, Decl. $+45°\ 11'\ 53''$ (1855)
$21\ 02\ 20.2$, $+45\ 22\ 35$ (1900).

The star is of about the 11th magnitude and at minimum falls to 12^m or lower. It was below its normal brightness on photographs taken 1899, May 10, $10^h\ 52^m - 13^h\ 28^m$ Moscow M. T. and 1900, Aug. 25, $9^h\ 23^m - 12^h\ 24^m$. The increase of light after a minimum was observed visually by M. Blajko Nov. 20, 1902, $6^h\ 09^m - 10^h\ 58^m$, Moscow M. T. From these data M. Blajko has found that the period is about 18 days or perhaps smaller.

New Variable Star 21.1902 Sagittæ.—This was also discovered by Mme. Ceraski and is announced in *A. N.* 3836. Its position is

R. A. $20^h\ 13^m\ 47^s$, Decl. $+20°\ 39'.0$ (1855)
$20\ 15\ 46$ $+20\ 47.3$ (1900).

Judging from seven photographs the brightness varies between the magnitudes 9.5 and 11.5 and the range may possibly be greater. The period is probably long, perhaps several weeks or months.

GENERAL NOTES.

The late appearance of the issues of this publication for this month and last is due to delay in securing half-tones from the engravers. Some of the work was unusually difficult, it being necessary to do it a second time, before satisfactory results could be obtained.

Selling Early Volumes of Popular Astronomy.—We have a few volumes of Popular Astronomy more than we wish to carry, especially volumes 1, 2, 3 and 4. We offer these for this month (February) for the *extremely low price* of one dollar per volume. These volumes are in pamphlet form, in perfect condition, and the cost of carriage will be prepaid to any part of the United States, Canada and Mexico. The colored star charts of the first two volumes could not be reproduced for hundreds of dollars.

Observations of the Light of Nova Persei.—Paper number 2 of the *Annals* of Harvard College Observatory contains a considerable number of observations of the light of Nova Persei which were made subsequent to those published in Popular Astronomy. The light curve of this interesting star is also given in this publication.

The programme of Section A of the American Association for the Advancement of Science for the Washington meeting is omitted this month for the lack of space.

Otto Klotz, Astronomer for the Department of the Interior, Canada, was recently in Cleveland to receive from Warner & Swasey the 15-inch refractor for the new Dominion Observatory at Ottawa. The lens is by Brashear. The equatorial, with spectroscope, photographic doublet and other attachments, is said to cost in the neighborhood of $15,000.

A Photograph of a Leonid Meteor.—Some time ago Dr. H. C. Wilson gave a description of a photograph taken by himself of a Leonid meteor, in these pages. W. H. Wesley, assistant Secretary and Librarian of the Roya l Astronomical Society, saw the account and asked to see the photograph. A lantern slide was made from it and sent to him. The following is his reply under date Jan. 15, 1903:

"I have to acknowledge, with many thanks, the receipt of the excellent lantern slide of your photograph of the Leonid meteor which you have kindly sent to the Society. It was thrown on the screen at our last meeting. It is an extremely interesting photograph."

Grants by the Carnegie Institution for Science Study.—January 24, the Carnegie Institution had a meeting in Washington, D. C., and made for original research work in science, literature or art the following large sums of money:

Astronomy	$21,000	Investigation of project for physical and geographical laboratory	5,000
Bibliography	15,000	Investigation for natural history projects	5,000
Botany	11,700	Marine biological research	12,500
Chemistry	1,500	Paleontology	1,600
Economics	15,000	Physics	4,000
Engineering	4,500	Physiology	5,000
Exploration	5,000	Psychology	1,600
Geology	12,000	Publications	5,500
Geophysics	8,500	Research assistants	25,000
History	5,000	Student research work in Washington	10,000
Investigation of project for Southern and Solar Observatory	5,000	Zoology	6,000

"The executive committee defines research as original investigation in any field, whether in science, literature or art.

"In the field of research the function of the institution should be organization, the substitution of organized for unorganized effort wherever such combination of effort promises the best results; and the prevention of needless duplication of work.

"The committee says it appears to be wiser at the beginning to make a number of small grants and to thoroughly prepare to take up some of the larger projects. Promising men are to be put upon research work under proper guidance and supervision."

Former President Gilman of Johns Hopkins University, in a signed summary of the year book, says:

"The methods of administration of the Carnegie institution thus far developed are general rather than specific.

"Efforts have been made and will be made to secure coöperation with other agencies established for the advancement of knowledge, while care will be exercised to refrain from interference or rivalry with them.

"For example, if medical research is provided for by other agencies, as it appears to be, the Carnegie institution will not enter the field. Systematic education will not be undertaken. Sites or buildings for other institutions will not be provided.

"Specific grants have been and will be made, for definite purposes, to individual investigators, young or old, of marked ability, and for assistance, books, instruments, apparatus and materials.

"It is understood that such purchases are the property of the Carnegie institution and subject to its control. The persons thus aided will be expected to report upon methods followed and results obtained.

"Appropriations will be made for publication, especially for the printing of papers of acknowledged importance, so abstruse, so extended or so costly that without the aid of this sum they may not see the light.

"With respect to certain large undertakings involving much expense, which have been or may be suggested, careful preliminary inquiries have been and will be made."

The Astronomical and Astrophysical Society of America.—This Society held its annual meeting in Washington, D. C., Dec. 29, 1902 to Jan. 1, 1903, in affiliation with Section A of the American Association for the Advancement of Science. The sessions were held in the assembly room of the Cosmos Club, those of Section A in the morning and those of the Astronomical Society in the afternoon. Both meetings were well attended and many of the papers presented were of very great interest and importance.

The writer does not have at hand a list of those present, but recalls with pleasure meeting Professor S. P. Langley, Secretary of Smithsonian Institution, Professor Simon Newcomb, President of the Astronomical and Astrophysical Society, Professor Asaph Hall, the retiring President of the A. A. A. S., Professor G. W. Hough, retiring Vice President of Section A., Professor G. C. Comstock, of Washburn Observatory, Professors G. E. Hale and E. B. Frost, of Yerkes Observatory, Captain C. M. Chester, Superintendent of the Naval Observatory with almost the entire force of Astronomers and Assistants at the Naval Observatory, Professor Ormond Stone, of the Leander McCormick Observatory, C. L. Doolittle of the Flower Observatory, F. L. O. Wadsworth of Allegheny Observatory, Father Hagen, of Georgetown College Observatory, Miss M. W. Whitney, of Vassar College Observatory, Miss Sarah F. Whiting, of Wellesley College Observatory, Miss Anna S. Young, of Mt. Holyoke, Dr. Herman S. Davis, Professor Charles S. Howe, Mr. J. A. Brashear, Mr. W. R. Warner, Professor J. R. Eastman, Professor J. M. Van Vleck, and many others.

It was a disappointment not to meet Professor C. A. Young and Professor Wm. Harkness, who were prevented by ill health from attending the meeting.

On Monday afternoon at 2:30 Vice President Hough addressed Section A (Mathematics and Astronomy) on "The Physical Constitution of Jupiter." This address is given in full as one of the leading articles in this number of POPULAR ASTRONOMY. At 4:00 o'clock Professor Newcomb gave the annual presidential address before the Astronomical and Astrophysical Society of America. His subject was "The Universe as an Organism." The address was published in *Science*, Jan. 23, so that we shall be able to give a full account of it later on.

The address of the retiring president of the A. A. A. S., Professor Asaph Hall, given on Monday evening, was also astronomical in character, his subject being, "The Science of Astronomy." It was a general account of the development and progress of science, and was published in *Science*, Jan. 2.

On Tuesday evening about fifty of the members of the Astronomical and Astrophysical Society enjoyed a formal dinner at "The Rauscher." The guests of honor were His Excellency the German Ambassador, Senator Morgan, Assistant

Secretary of State Hill, and Capt. Chester, the Superintendent of the U. S. Naval Observatory.

On Wednesday afternoon, a very pleasant reception was given to the members of the Society by Captain and Mrs. Chester at the Superintendent's residence at the Naval Observatory, after which all who desired were shown the various buildings and instruments of the Observatory. The evening was clear and quite a number were given the satisfaction of looking through the 12-inch and the 26-inch telescopes.

The officers elected for the ensuing year were:

President—Simon Newcomb.
Vice Presidents—George E. Hale, Wm. W. Campbell.
Secretary—George C. Comstock.
Treasurer—Charles L. Doolittle.
Councilors—Ormond Stone, W. S. Eichelberger.

The program consisted of thirty-six papers the most of which were read either in full or in abstract by the authors or their friends. A few only were by title. The writer took few notes at the time and so will not attempt to comment on many of the papers.

1. A Comparison of Astronomical Photographic Measures made with the Reseau and without it. Dr. Harold Jacoby, Columbia University, New York.

The American astronomers who took photographs for the determination of the parallax of Eros made no use of the reseau. The results of comparisons made by Dr. Jacoby show that the measures of plates without the reseau are equally accurate with those of plates with the reseau.

2. Periodic Solutions of the Problem of Four Bodies. Professor E. O. Lovett, Princeton University.

3. On the Integrals of the Problem of n Bodies. Professor E. O. Lovett, Princeton University.

4. On Certain Matters connected with Spectroscopic Methods. Professor W. J. Humphreys, University of Virginia.

Two points of importance were brought out by the writer. The first was a method of increasing the intensity of the lines in a photograph of a weak spectrum by means of reflectors placed above and below the slit, either in front of or behind the slit, and also above and below the ruled part of the grating in order to throw upon the grating light that would otherwise escape. Mr. Humphreys showed photographs in which, by maladjustment of the reflectors, the lines were triple, and others in which the adjustment was good so that three images were perfectly superimposed.

The second point was that silvered reflectors and speculum metal gratings are unsuitable for the study of the ultra-violet spectrum since at about wavelength 3200 silver reflects only four per cent of the light which falls upon it.

5. Spectra of Stars Secchi's Fourth Type. Professor George E. Hale, Ferdinand Ellerman and J. A. Parkhurst, Yerkes Observatory.

The paper was presented by Professor Hale and was illustrated by steropticon views showing the spectra of various stars of the Fourth Type as photographed at the Yerkes Observatory. There were marked differences between spectra shown, but they could be arranged in such an order as to show a gradation from one to the other, corresponding perhaps to the successive stages in the development of the stars. Conclusive proof was given that there are bright lines in the spectra of stars of this type.

6. Radial Velocities of Twenty Stars having Spectra of the Orion Type. Professor E. B. Frost and W. S. Adams, Yerkes Observatory.

This paper was presented by Professor Frost and consisted of explanations of and comments upon the following table, which gives the results of measurements of spectrograms obtained with the Bruce spectrograph of the 40-inch Yerkes telescope. The proper motions were given by Professor Frost but the positions and magnitudes we have added from the best available sources.

Star.	Radial Velocity. km.	Proper Motion. ″	R. A. h m s	Decl. ° ′	Magn.
γ Pegasi	+ 5	0.018	0 08 05	+ 14 38	2.8
ζ Cassiopeiae	+ 3	0.020	0 31 24	+ 53 21	3.8
ε "	− 6	0.036	1 47 12	+ 63 11	3.5
ζ Persei	+ 22	0.026	3 47 51	+ 31 35	3.0
β Orionis	+ 21	0.018	5 09 44	− 8 19	0.3
γ "	+ 18	0.029	5 19 46	+ 6 16	1.7
ε "	+ 27	0.020	5 31 08	− 1 16	1.7
ζ "	+ 17	0.016	5 35 43	− 2 00	1.9
κ "	+ 17	0.015	5 43 01	− 9 42	2.2
β Canis Majoris	+ 32	0.025	6 18 18	− 17 54	2.0
ε " "	+ 27	0.012	6 54 42	− 28 50	1.6
η Leonis	+ 3	0.021	10 01 53	+ 17 15	3.6
γ Corvi	− 7	0.185	12 10 40	− 16 59	2.7
τ Herculis	− 13	0.036	16 16 44	+ 46 33	3.9
ζ Draconis	− 14	0.029	17 08 30	+ 65 50	3.2
ι Herculis	− 16	0.016	17 36 39	+ 46 04	3.9
67 Ophiuchi	− 4	0.028	17 55 38	+ 2 56	4.0
102 Herculis	− 11	0.015	18 04 28	+ 20 48	4.5
η Lyrae	− 9	0.020	19 10 21	+ 38 58	4.6
ε Delphini	− 26	0.020	20 28 26	+ 10 58	4.0

It will be noticed at once that the stars in this list between 3^h and 7^h R. A., all have a positive radial motion, *i. e.*, they are receding, while those in the opposite part of the heavens, R. A. 16^h-20^h are approaching, the signs being all negative. This is explained by the fact that the solar system is moving toward the one part of the heavens and away from the other. Professor Newcomb commented upon this, and said that it was remarkable that, if the solar motion be subtracted from those of the table, the remaining motions of the whole group of stars are very small, scarcely any having so great a velocity as the Sun.

7. Preliminary Summary of Magnetic Results Obtained During the Recent Eruptions in Martinique. Louis A. Bauer, U. S. Coast Survey.

One remarkable statement was that a notable deflection of the horizontal force needle was recorded at, so far as has been determined, the same moment the world over, at the time of the St. Pierre disaster, while no records of a disturbance were found upon the seismographs. At the time of another earthquake, which was recorded upon the seismographs, a slight magnetic disturbance was noted but at later moments at more distant stations.

8. The Motion of 85 Pegasi. Professor George C. Comstock, Washburn Observatory.

In the course of a study of the motion of the brighter component of this pair Professor Comstock undertook to find the ratio of the masses of the two stars, reaching the almost incredible conclusion that the brighter star has less mass than its very faint companion. From the solution of equations for the two coordinates x and y separately, the ratio comes out 0.61 and 0.63 respectively. Professor Comstock said he would vouch for the correctness of his figures but would leave the explanation to others.

9. Preliminary Account of an Investigation of the Proper Motions of Faint Stars. Professor George C. Comstock, Washburn Observatory.

10. Astronomical Laboratory Work for Large Classes. Sarah F. Whitney, Wellesley College Observatory.

This was illustrated with stereopticon views showing the appliances used by Miss Whitney in her work of instruction.

11. The New Gases, Neon, Krypton, and Zenon in the Chromosphere. A. S. Mitchell.

12. New Spectroscopic Binaries. Professor E. B. Frost and W. S. Adams, Yerkes Observatory.

In the course of the work at Yerkes Observatory three new spectroscopic binaries have been discovered. The following data were given by Professor Frost:

Star.	Mag.	No. of Plates Measured.	Radial Velocity.
δ Ceti	4.1	11	+ 16 to + 6
ζ Tauri	3.0	10	+ 34 to + 7
ν Eridini	4.0	5	+ 26 to + 3

13. The Wave-Lengths of Rydbergs First Line of Hydrogen (λ 4886) and Others. Professor E. B. Frost and W. S. Adams, Yerkes Observatory.

14. On Certain Spectrum Bands. W. J. Humphreys, University of Virginia.

15. Spark Spectra in Liquids and Their Bearing on the Spectra of Temporary Stars. Professor George E. Hale and N. A. Kent, Yerkes Observatory.

16. Form and Structure of the Galaxy. Professor F. W. Very, Washington, D. C.

17. A Method of Computing Orbits in Rectangular Coördinates. Professor A. O. Leuschner.

18. Notes on the Short Method of Determining Orbits from Three Observations. Professor A. O. Leuschner.

19. The Solution of the Orbit Irrespective of Parallax and Aberration. A. O. Leuschner.

20. The Orbit of Comet 1902 *a*. Professor A. O. Leuschner.

21. On an Automatic Device to Forestall the Dewing of Objectives. Professor D. P. Todd, Amherst College Observatory.

22. On a Highly Favorable Type of Instrument for Photographing the Solar Corona. Professor D. P. Todd, Amherst College Observatory.

23. An Inquiry into the Cause of the Nebulosity Around Nova Persei. Professor F. W. Very, Washington, D. C.

24. The Pressure of Light and Its Illustration in the Construction of a Laboratory Comet's Tail. Professor E. F. Nichols and G. F. Hull.

This was an exceedingly interesting paper, presented by Mr. Hull. In the experiment, dust from the ordinary puff-ball (if we remember correctly) had been specially dried and placed in a vacuum tube having a partition with a small aperture. When this tube was inverted and a ray of light thrown upon it, the particles falling through the aperture were driven away from the light producing a pretty illustration of a comet's tail. It seemed a pity to have Mr. Hull say at the close of the paper that just before coming in he had found an error in their computations and that the observed deflection seemed to give too great a value for the pressure of light, and that it must be due partly at least to the effect of some gas remaining in the particles in the tube.

25. Improvement in the Mounting of Fixed Meridian Instruments. Professor G. W. Hough, Dearborn Observatory.

Professor Hough condemned the use of brick piers, saying that the coefficients of expansion of brick and the metals were so different that the connection between the pier-heads and the piers became loose. He recommended solid sandstone piers, with the microscopes set in the piers, and showed the improvement in the level and azimuth changes in the meridian circle of Dearborn Observatory when so mounted.

26. The Theory of Non-Spherical Surfaces in the construction of Telescope Objectives. Professor F. R. Moulton, University of Chicago.

27. The Orbit of the Spectroscopic Binary η Orionis. W. S. Adams, Yerkes Observatory.

This paper was red by Professor Frost. He stated that η Orionis has the greatest range of radial motion of any known binary, viz.: $+180^{km}$ to -100^{km}. The period is very nearly 8 days.

28. Photometric and Photographic Observations of Faint Variable Stars. J. A. Parkhurst, Yerkes Observatory.

29. The Parabolic Value of the Aberration Constant. Dr. S. C. Chandler, Cambridge, Mass.

This paper, an abstract of which, was read by Professor Doolittle, has since been printed in the *Astronomical Journal* No. 529, and the figures are there slightly changed. The author thinks the time has come for a revision of the adopted value of the aberration constant and suggests 20″.52. The following is a summary of values collected by Mr. Chandler obtained by different methods:

	Determinations.	Aberration.	Weight.
		″	
Zenith Telescope, Talcott's Method	26	20.524	159
Meridian Circle, Declinations	10	20.513	22
Prime Vertical Transits	3	20.528	24
Right Ascensions	3	20.53	6
Prismatic Apparatus	2	20.48	5
	44	20.523	216

Unweighted mean 20″.526 ± 0.006.
Weighted mean 20 .523 ± 0.005.

This value corresponds to the value of the solar parallax 8″.780.

30. Observations and Light Curves of Some of the Small Variable Stars Found in the Globular Clusters. Professor E. E. Barnard, Yerkes Observatory.

31. On the Micrometrical Triangulation of the Stars in the Great Globular Clusters, M. 3, M. 5, M. 13 and M. 92. Professor E. E. Barnard, Yerkes Observatory.

32. The Light of the Stars. S. D. Townley, Lick Observatory.

33. Results of Meridiad Observations for Stellar Parallax made at the Washburn Observatory. Albert S. Flint, Washburn Observatory.

This paper, one of the most important of the session, was presented by Professer Comstock, and gave the results obtained for the parallaxes of nearly one hundred stars. The detailed observations have since appeared in Vol. XI of the Publications of the Washburn Observatory, and a fuller notice of them will be given elsewhere.

34. The Photoheliograph of the U. S. Naval Observatory, Its Use and Defects in Solar Photography. George H. Peters, U. S. Naval Observatory.

One important point was the large change of focus, due to change in temperture, amounting to about half an inch during the year, in the 40-foot photoheliograph. This was attributed principally to the change in figure of the concave glass reflector, showing that, in this form of instrument, very careful attention must be paid to the focussing of the instrument at different temperatures in order to secure good results.

35. The Constant of Aberration from Zenith Telescope Observations, 1901-1902. Professor Charles L. Doolittle, Flower Observatory.

Professor Doolittle gave 20″.510 as his mean result for the years 1901-2, and the following comparison of results for the past 13 years:

Year.	Aberration.	Weight.	Year.	Aberration.	Weight.
	″			″	
1889-90	20.448	¼	1898	20.540	1
1892	20.551	1	1900	20.561	1
1894	20.537	1	1901-2	20.510	1
1896	20.580	½		mean 20.539	

36. Statement of the Progress made by the Watson Trustees in Computing Tables of the Asteroids Discovered by James C. Watson. Professor Simon Newcomb, Washington, D. C.

Professor Newcomb said that for a long period nothing had been done, for the reason that the income from the fund left by Professor Watson had been entirely inadequate for the purpose. The income had been allowed to accumulate, so that now the trustees were in position to arrange for the speedy completion of the work, which had been given into the charge of Professor A. O. Leuschner.

The American Inventor, Washington, announces that it has recently purchased *Popular Science News* and that hereafter the new journal, issued semi-monthly, will contain not only its usual illustrations and notices of "the latest developments in the arts and sciences, and to the American Inventor," but a department titled "Science News," in which will appear the features familiar to the readers of the *Popular Science News*, such as animal life, plant life, archeology, mineralogy, etc.

The first issue of the new journal appeared January 15th and as the subscription price of the two journals was the same, the *American Inventor* will be sent to all unexpired subscriptions of *Popular Science News*, as well as to the list of the new journal.

Elements and Ephemeris of Comet *d*, 1902 (Giacobini).—The elements and ephemeris of Comet *d*, 1902 which are here given are based upon my observations of December 5 and 30, 1902 made with the 12-inch equatorial and of January 17, 1903 made with the 36-inch. The comet is very small with a well defined condensation a little preceding the center. On the 17th of January it was estimated as equal to a 12th magnitude star in brightness.

ELEMENTS.

$T = 1903$ March 23.27958 G. M. T.
$\omega = 5° 45' 4''.4$
$\Omega = 117 \ 28 \ 0 \ .0$ } Mean equinox of 1903.0
$i = 43 \ 53 \ 57 \ .9$
$\log q = 0.443156$

Residuals (O — C)

$\Delta\lambda' \cos\beta' = -3''.6$; $\Delta\beta' = -3''.1$

Constants for the Equator of 1903.0.

$$x = v\,[9.896716]\,\sin\,(221^\circ\ 33'\ 31''.7 + v)$$
$$y = v\,[9.999990]\,\sin\,(131\ \ 15\ \ 44\ .4 + v)$$
$$z = v\,[9.789065]\,\sin\,(\ 40\ \ 46\ \ 31\ .3 + v)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1903.	True α	True δ	log Δ	log r	Brightness.
	h m s	° ′ ″			
Feb. 13.5	6 37 22.6	+ 17 48 3	0.3051	0.4474	0.94
15.5	37 0.2	18 25 14			
17.5	36 44.1	19 1 50	0.3122	0.4466	0.92
19.5	36 34.3	19 37 49			
21.5	36 31.0	20 13 8	0.3200	0.4458	0.89
23.5	36 34.2	20 47 46			
25.5	36 44.0	21 21 41	0.3283	0.4451	0.86
27.5	37 0.4	21 54 52			
Mar. 1.5	37 23.4	22 27 19	0.3369	0.4446	0.83
3.5	37 53.1	22 59 1			
5.5	38 29.3	23 29 58	0.3458	0.4441	0.79
7.5	39 12.1	24 0 9			
9.5	40 1.5	24 29 35	0.3550	0.4437	0.76
11.5	40 57.2	24 58 15			
13.5	41 59.1	25 26 8	0.3644	0.4434	0.73
15.5	43 7.3	25 53 15			
17.5	44 21.5	26 19 37	0.3739	0.4433	0.70
19.5	45 41.8	26 45 13			
21.5	47 8.0	27 10 5	0.3834	0.4432	0.67
23.5	48 40.0	27 34 12			
25.6	6 50 17.8	+ 29 59 34	0.3929	0.4432	0.64

R. G. AITKEN.

LICK OBSERVATORY, University of California.
January, 1903.

The Miniature Dumb-bell Nebula, Messier 76.—This object if N. G. C. 650 and 651 (M. 76 and H. I. 193). Its position for 1900 is

$$\alpha = +\,1^h\,36^m.0;\quad \delta = +\,51^\circ\,4'.$$

This is 53′ north of the 4.20 magnitude star F 54 Andromedae and $1^m.3$ preceding the 6.80 magnitude star DM. + 50°336.

Webb's *Celestial Objects* says of it: "Pearly wh. neb., double; curious miniature of M. 27, and like it *gaseous*, *p* a little the brighter. E. of Rosse, spiral."

I ran across this object on 1903, January 1, while sweeping for comets with the ten-inch Clark refractor. At first sight, with a power of forty, it appeared simply as a hazy, elongated object, just visible in the three inch finder as a very small nebulous spot. With a power of one hundred it was seen to resemble a dumb-bell even more closely than the celebrated nebula which bears that name. It looks as if it were composed of two spherical nebulas, almost touching, and joined together by a delicate, indefinable bridge of mist. Each nucleus brightens somewhat towards its center. The preceding nucleus is a little larger than the other and about one and one-half times as bright. In it, with a power of about two hundred I glimpsed four or five excessively faint stars, two of which I saw without any doubt and estimated their brightness at $14^m.2$ each. No stars were seen in the fainter nucleus although it was carefully examined with high powers. The power of two hundred, however, showed the nebula as a whole best of all.

ZACCHEUS DANIEL.

BUCKNELL UNIVERSITY, Lewisburg, Penn.,
1903, January 15.

Ancient Astronomy from the Excavations at Nippur.—A most important article appeared in the February number of *The International Evangel*, 1903, entitled "Professor Hilprecht's Excavations at Nippur," by Allan Sutherland, which briefly details the work undertaken by the fourth expedition sent out by the University of Pennsylvania to excavate a city in the land where Eden is supposed to have been located, and where Abraham was born. It is said in this article that the work of this expedition has reached a successful climax, and has accomplished wonderful results. Its author claims that the discoveries made in unearthing Nippur bring to light the foundations of the city that were laid 4000 years before the time of Abraham.

The persons in charge of this most recent work are Professor H. V. Hilprecht, scientific director, J. H. Haynes, field director, and Messrs. Valentine Geere and Clarence Fisher, architects.

The Parthian palace has been completely explored and more than 1,000 burials in different parts of the ruins have been examined. These recent explorations have definitely located the famous library of Nippur from which thousands of tablets have been taken, besides many other objects bearing inscriptions of interest. Some mentioned are a votive table of Naram-Sin, a large diorite vase, etc., etc. It is reported that about 23,000 tablets and fragments have been found which are mostly of a literary character. This is but one of the important discoveries made in this expedition.

As the excavators continued their work down through 25 feet of accumulation of debris, representing several thousands of years of history, "they found a series of rooms, a number of which contained shelves built out from the wall for the purpose of laying out the tablets in rows. The library seems to have been divided into two parts: the business section for keeping accounts, and the educational quarters with a vast library of a literary character."

It appears that only a small portion of this large building has yet been cleared, possibly about one twentieth part of the entire library. It is estimated that the entire collection when secured will amount to 150,000 tablets, every one of which belongs to the third millenium before Christ. But what interests us most is the very general character of this great library. In it are found lists of birds, animals, plants, stones; lists of words for chairs, stools, furniture, hymns, astronomical and mythological inscriptions, etc., etc. The remarkable statement is also made that the people 2300 years B. C., knew that the Earth was a globe, and that their astronomers then took the same view of celestial phenomena that we do now.

Astronomy will doubtless reap a rich harvest from the contents of this very old library of Nippur when it is more fully read.

BOOK NOTICES.

Dr. Luis G. Leon of the Astronomical Observatory of Mexico, has favored us with two of his interesting booklets, one concerning the planet Mars, and another about the marvels of the heavens. They are fully illustrated and popular in character and written in Spanish.

Field Astronomy for Engineers.—Professor George C. Comstock, Director of the Washburn Observatory, and Professor of Astronomy in the University of Wisconsin, has published a text-book of Field Astronomy for Engineers. In size it is 8vo., 212 pp., illustrated, cloth, $2.50, and published by

Messrs. John Wiley and Sons of New York. Professor Comstock has for many years been giving instruction in the elements of practical astronomy to students of engineering, and he has learned their wants by practical experience thus acquired. This new book is the result of his thought and his work especially in this line.

The parts of astronomical practice which the author deems most important in engineering instruction are. 1. Training in numerical computation; 2. Training in the accurate use of the sextant and the theodolite, with reference to the elimination of errors from the results of observation, and 3. Determination of time, latitude and azimuth with portable instruments, for furnishing matter for practice work.

The first chapter deals with the elements of spherical trigonometry, because students who begin the engineering course have not usually had enough of this branch in their mathematical studies previously to enable them to go on without such preparation. Attention is called to approximate formulae, numerical computations, logarithmic tables, and the limits of accuracy.

Next the author considers coördinates; fundamental concepts, definitions, notation table of coördinates, and the transformations of coördinates.

Chapter III is devoted to time, in which are presented three time systems, longitude, conversion of time, chronometer corrections and the almanac.

Chapter IV deals with corrections to coördinates, such as the dip of the horizon, refraction, semi-diameter, parallax and diurnal aberration. The two following chapters have to do with rough or approximate determinations of time, latitude, azimuth, etc., while the next three are given to the study of instruments, accurate observations, and theoretical adjustments which supposes independent and original engineering work.

The strong points in Professor Comstock's new book for the place intended, are its plain and practical methods, its correct and useful data, and its graded matter, that will naturally lift a student to the plane of some comprehension of the noble field of work that belongs to a successful engineer.

Knowledge Diary and Scientific Handbook for 1903.—The publishers of *Knowledge*, London, 326 High Holborn, W. C., have furnished us a copy of the Knowledge Diary and Scientific Handbook for 1903. This, the third annual issue in the series is fully up to its companions and contains a large amount of useful matter for persons interested in Astronomy and kindred topics. We have had and used even for diary purposes, as well as handbook reference the two preceding volumes. We know of nothing else so good and so handy for both purposes.

Correction.—In the December 1902 issue of POPULAR ASTRONOMY the visual rediscovery of Eros at the Chamberlin Observatory last August was attributed to me. The re-discovery was really made by Dr. Chas. J. Ling, to whom the credit is due. HERBERT A. HOWE.